

**June 1999**



# **EARTH SCIENCE ENTERPRISE TECHNOLOGY STRATEGY**



National Aeronautics and  
Space Administration

## The Cover

The sequence of Earth views is derived from images enabled by space-based remote-sensing technologies. From top to bottom, the images present the following information:

- Atmospheric water vapor is an important factor in determining local weather and global climate. In this composite time-lapse sequence of atmospheric water vapor, the hurricanes of 1995 can be seen forming off the coast of Africa and moving west across the Atlantic to the east coast of the United States.
- The oceans, atmosphere, and land all play critical roles in sustaining life on Earth. The characteristics of ocean currents, wind patterns, and topography can make one area a desert and another area a rain forest. The Earth is bathed in energy from the Sun. The oceans absorb and are heated by this energy. This composite time-lapse sequence shows temperature patterns in Earth's oceans. The temperature is color coded, with red indicating the warmest areas and blue the coldest.
- Using images such as this, time-lapse sequences can show changes in the distribution of Earth's vegetation over a 1-year period. Vegetated areas appear in shades of green. The vast deserts of North Africa, the Arabian Peninsula, and Central Asia are distinguishable by a lack of vegetation. Monitoring Earth's vegetation is important in tracking the effects that result from changes in climate and human activities.
- With global sea-surface temperature data, it is possible to monitor changes in oceanic circulation that sends warm Western Pacific water into the cooler water of the Eastern Pacific. This is known as an El Niño. An El Niño can disrupt the marine ecosystem because phytoplankton existing at the base of the marine food chain do not flourish in the warm, nutrient-poor water from the Western Pacific. As a result, the fish and marine mammals that depend on phytoplankton for food may die or migrate in large numbers.
- As oceanic plates are driven under continental plates into Earth's mantle, they begin to melt. The molten rock rises to the surface, forming volcanoes. This visualization shows volcanic eruptions from 1960 to 1994. Most of the volcanoes are located near plate boundaries.

These images and many others can be found at the Goddard Space Flight Center Scientific Visualization Studio web site:  
<http://svs.gsfc.nasa.gov/imagewall.html>

Dear Colleagues, Customers, and Partners:

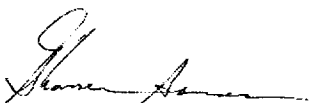
The ultimate goal of the Earth Science Enterprise (ESE) is to expand and apply scientific knowledge of the Earth system using NASA's unique vantage point of space combined with airborne and in situ platforms. Advances in technology will play a critical role in shaping the ESE research programs of the future. To ensure timely technology availability, the Enterprise has established a strategically driven technology development program with two primary objectives. The first is to accomplish the defined ESE missions more efficiently and effectively, and the second is to enable new fundamental and applied research programs essential for meeting the long-term Enterprise goals.

The enclosed Technology Strategy lays out the Enterprise approach for accomplishing this newly initiated Technology Development Program (TDP). The TDP is a major component of the new paradigm for implementing and managing ESE. Requirements for the TDP are derived directly from the ESE Research and Applications Implementation Plans. Specific technology program investments are based on rigorous assessments that identify and weigh various technology solutions to meet the science and applications measurement capabilities and targeted infusion need dates. Investment plans are coordinated with the research and applications organizations. Investments take two paths: (1) a long-term exploratory path that identifies new innovative technology and (2) a nearer term path that takes the most promising technologies and advances them to a higher level of development for infusion into ESE missions. To support near- and midterm missions (those having infusion need dates in the next 2–6 years), implementation approaches such as the Instrument Incubator Project (formerly Program) and ESE-unique core technology development initiatives are being established that identify and accelerate the development of key instrument components, measurement subsystems, and advanced information systems capabilities. The New Millennium Program, jointly sponsored with the Space Science Enterprise, is to be the ESE's major approach for space demonstration of advanced measurement concepts. An ESE Advanced Concepts Studies program linked to the emerging Strategic Vision and Architecture for the Enterprise will identify the more far-term technology needs and opportunities. Such efforts will be coordinated with studies being conducted by the recently initiated Agency-level program at an Institute for Advanced Concepts. Thrust areas, priorities, and joint investment concepts for these far-term needs will be established with cooperating technology programs, such as NASA's Cross Enterprise Technology Development Program and the recently initiated Information Technology for the 21st Century (IT<sup>2</sup>). ESE will seek partnerships, including the use of leveraged joint investments with other Government and private-sector organizations outside NASA.

To ensure synergy with overall Agency-level technology development policies and thrust areas, the ESE Technology Investment Plans will be measured against objectives set by the Agency. Also, the TDP will establish and seek guidance from a Technology Subcommittee of the ESE Earth System Science and Applications Advisory Committee.

This document emphasizes the importance that the Enterprise is now placing on the development of evolutionary and revolutionary technologies to ensure the continued growth and vitality of the science and applications programs. The TDP will strive to meet the grand challenges being established for the Enterprise through the articulation of the Enterprise Strategic Vision and Architecture. Quantitative performance metrics and targets have been established and will be used in judging the success of the program.

This document provides strategic guidance for the Enterprise's TDP. It is a critical first step toward a viable and productive relationship not only with the program's primary customers—the science and applications communities—but also the strongly linked cross-Enterprise programs and potential external partnerships. We look forward to working with you to achieve this goal.



Ghassem R. Asrar  
Associate Administrator for Earth Science



Samuel Venneri  
NASA Chief Technologist





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## The Technology Imperative

**N**ASA's Earth Science Enterprise (ESE) is dedicated to understanding the total Earth system and the effects of natural and human-induced changes on the global environment. The goals of ESE are:

- Expand scientific knowledge of the Earth system using NASA's unique vantage points of space, aircraft, and in situ platforms
- Disseminate information about the Earth system
- Enable the productive use of ESE science and technology in the public and private sectors

ESE has embraced the NASA Administrator's better, faster, cheaper paradigm for Earth observing missions. We are committed to launch the next generation of Earth Observing System (EOS) missions at a substantially lower cost than the EOS first series. Strategic investment in advanced instrument, spacecraft, and information system technologies is essential to accomplishing ESE's research goals in the coming decades.

Advanced technology will play a major role in shaping the ESE fundamental and applied research program of the future. ESE has established an Earth science technology development program with the following objectives:

- To accomplish ESE space-based and land-based program elements effectively and efficiently
- To enable ESE's fundamental and applied research programs goals as stated in the NASA Strategic Plan

The strategy defined in this document serves as the guide for planning and prioritizing competing technology opportunities and for constructing the ESE technology investment portfolio such that it best supports these objectives. The planning process provides the critical bridge between the technologists and the scientists. To fully leverage external investments, the overall strategy stresses the critical exploitation of complementary technology development programs and the aggressive search for mutually beneficial partnerships. ESE has set a target value of investing 10 percent of its total annual budget in technology development.

This strategy document supports the ESE Strategic Enterprise Plan, and will be updated as science and applications research priorities, program needs, and technological capabilities evolve. Appendix 1 lists the acronyms and abbreviations used in this document, and Appendix 2 provides links to relevant web sites.







## The Driving Vision

**T**he Earth Science Enterprise embraces a long-term programmatic vision comprising several key scientific challenges:

**Global Water and Energy Cycle**—Improved understanding of the global water cycle to enable effective prediction of hydrologic regimes on a regional scale.

**Climate Variability and Prediction**—Improved understanding of the coupled climate system to enable prediction of climate variations and assessment of long-term trends.

**Atmospheric Chemistry**—Improved understanding of atmospheric composition and chemistry to enable prediction of future changes in ozone, surface ultraviolet radiation, and global pollution.

**Biology and Biochemistry of Ecosystems and the Global Carbon Cycle**—Improved understanding of the processes and patterns of the Earth's biological productivity and land cover and assessment of the role of the biosphere in the global carbon cycle.

**Solid Earth Science**—Improved understanding of the mechanics of the Earth's interior and global geological processes that shape the topographic surface of the Earth and assessment of possible resulting natural hazards.

**Interdisciplinary Earth System Science**—Assurance that all important forcing and feedback mechanisms are accounted for in addressing the full range of interdisciplinary Earth science issues.

Such challenges lead to a technology program that has as its driving vision: “. . . Enabling the acquisition and dissemination of environmental earth science information to anyone, anywhere, anytime.” The technology

strategy necessary to meet this vision derives from a measurement and operational architecture that views the challenges from an end-to-end system perspective. Measurement approaches will evolve from the characterization of Earth through individual measurements to the goal of assessing and forecasting the state of the Earth system based on the fusion of multiple measurement sets into a comprehensive global model. Commercial data sources will be sought, as well as archived U.S. and international data sets, and data from all these sources will be assimilated into this family of evolving global models. The overall architecture will advance to encompass the implementation of multiple ground, air, and space assets as a reconfigurable system to acquire the desired information.

This vision embodies the long-term Earth science goal of understanding Earth and its environment as a global system and the concomitant ability to use this model for predicting future behavior of both local, rapidly changing phenomena and long-term, gradual shifts in the global ecosystem.

Significant advances in technology are required to bring about this vision of multidisciplinary campaigns combining ground, air, and space assets into a single reconfigurable system, as depicted in Figure 1. With the expectation of continuing budget pressure, it will also be imperative for ESE to accomplish these challenging goals in a most economical way. This will require instruments and spacecraft that are inexpensive to develop, deploy, and operate, as well as information system architectures that provide easy access and sophisticated cross-reference queries for a broad range of users.

In the NASA spirit of reducing overall life-cycle cost, ESE will participate in the NASA Intelligent Synthesis Environment (ISE) thrust. ISE addresses an important element of the future technology direction of NASA in

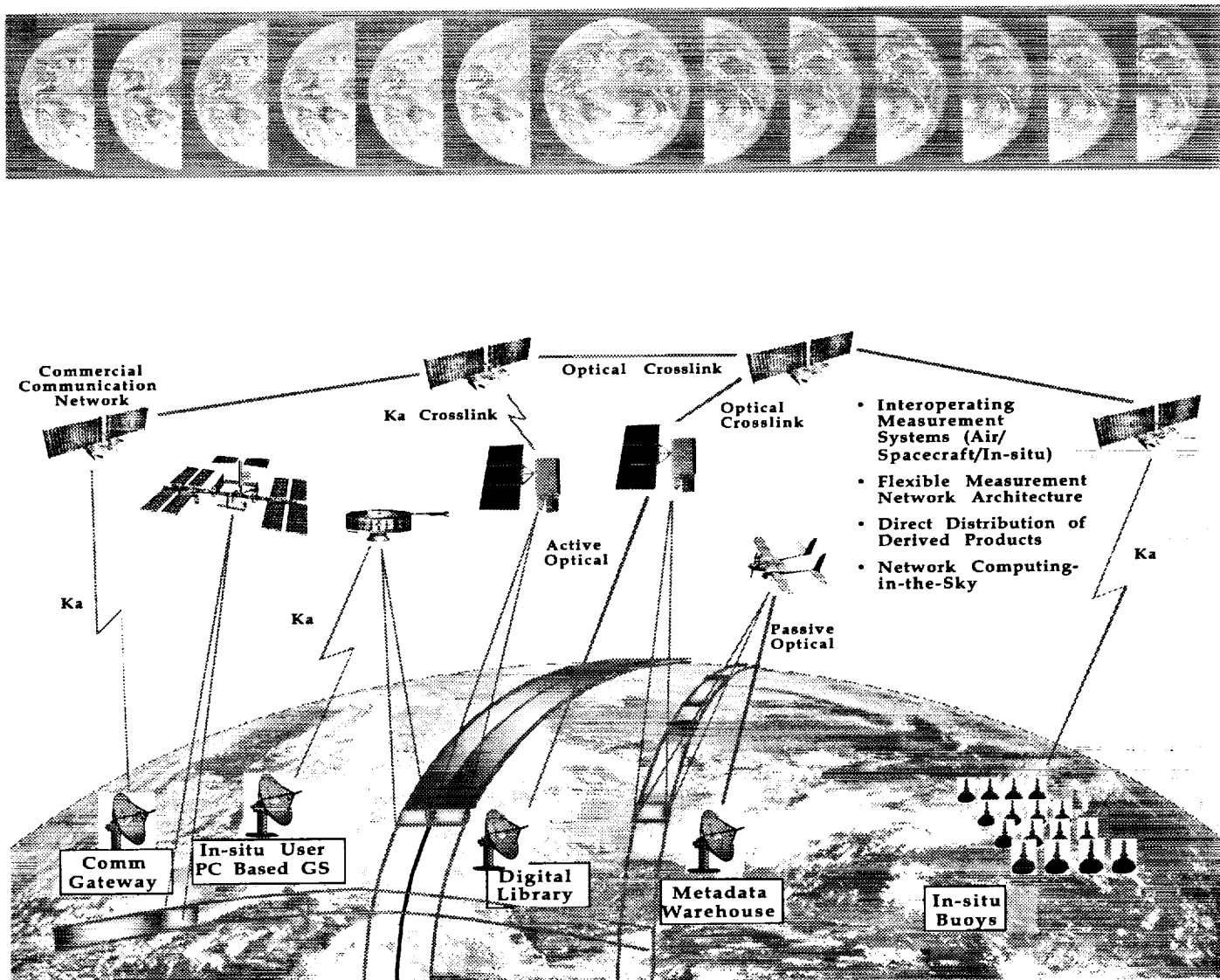


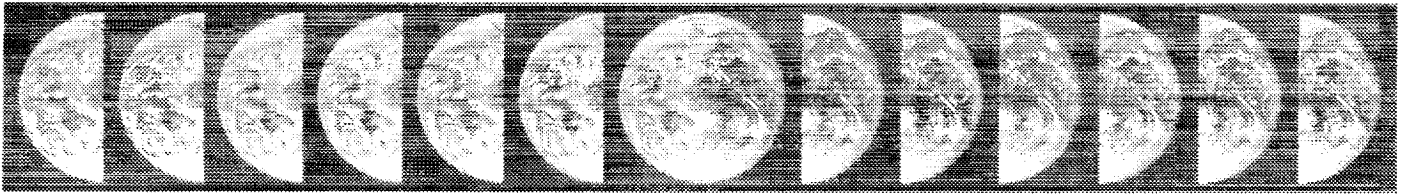
Figure 1. Earth Science System Vision

creating a scientifically based mission engineering practice of collaborating with NASA Centers, industry, and the academic community. To achieve evolutionary mission design that can be closely integrated with fabrication and integration and test, advanced mission simulation tools will be employed. To reduce overall life-cycle development time, concurrent development, and iterative refinement, integrated and collaborative design methods will be used.

In an era of growing commercial activity in space-based Earth observations, ESE will refrain from building and maintaining technology that is being pursued by the private sector. This will be accomplished by fostering and exploiting commercial remote-sensing data sources wherever feasible—and, in particular, where the measurement

set calls for sustained observations over long periods of time. Technology programs will be aligned to stress the development of the sensors, space architectures, and decision systems that underpin the ability of commercial flight systems to meet ESE's needs.

As a means of lowering overall life-cycle costs of the ESE program to the Nation and avoiding unnecessary duplication of space infrastructure, the Department of Defense (DoD) and the National Oceanic and Atmospheric Administration (NOAA) of the Department of Commerce were directed to converge on a single space system to provide certain environmental information common to the civil and national security requirements. The joint system is called the National Polar-orbiting Operational Environmental Satellite System (NPOESS).



NASA is chartered to participate in this activity through its role in developing new Earth remote-sensing instrument and spacecraft technologies that could potentially improve the capabilities of the operational system. ESE also looks to NPOESS as a source of long-term systematic Earth observations where appropriate. The three agencies have established an Integrated Program Office (IPO) to manage the converged system.

The vision for the future also demands immediate, broad information dissemination to extend the benefits of ESE science and applications research and data to a broader community. Maximum public impact entails the near-real-time availability of video rate information on global and local atmospheric, ocean, and land measurements acquired by NASA's ground, air, and space-based assets.





## Technology Focus

**A** high-level ESE strategic technology roadmap aligned with the NASA Strategic Plan is shown in Figure 2. Toward the goal of expanding human activity and space-based commerce in the frontiers of air and space, ESE identifies three interlinked themes. First, ESE will lead the way in the development of highly capable remote and in situ instruments and the information system technologies needed to support coupled Earth system studies that together will enable the affordable investigation and broad understanding of the global Earth system. Second, ESE will emphasize the development of information system architectures to increase the number of users of Enterprise information from several thousands currently to several tens of thousands during the next 5–7 years, with the goal of providing easy access to global information for science, education, and applications. Finally, ESE will work in partnership with industry and operational organizations to develop the capabilities and infrastructure to facilitate the transition of sustained measurements and information dissemination to commercial entities.

These evolving demands result in technology objectives that will be captured as ESE's Level I Requirements organized in three categories. Examples of enabling technologies are depicted in figures interspersed throughout the remainder of the document. For instance, see Figure 3.

### Instruments

The main objective is to develop advanced instruments and measurement technologies and/or smaller, but more capable versions of current ones in support of scientific investigations that will expand knowledge of the Earth system using unique vantage points of space, aircraft, and in situ platforms. These include:

- Instrument and sensor architectures that provide significant reductions in life-cycle costs by decreasing mass, launch volume, power, and operation complexity for the whole spectrum of Earth observing instruments
- Instrument and sensor architectures that enable new, high-priority science in support of the Enterprise research priorities
- Active sensors for space-based lidar and radar applications with improved lifetime, efficiency, and performance and with reduced mass, launch volume, and cost
- Detector arrays and passive sensing systems covering a portion of the electromagnetic spectrum of interest to Earth science that reduce instrument accommodation requirements and that simplify calibration, integration, and operations
- Miniature, self-contained deployable instrument packages for in situ measurements

### Flight Systems and Operations Capability Development

Cutting-edge technologies, processes, techniques, and engineering capabilities will reduce development and operations costs and support rapid implementation to support productive, economical, and timely missions. These include:

- Techniques and algorithms that enable the achievement of science objectives through the formation flying of small spacecraft, including calibration and data fusion considerations

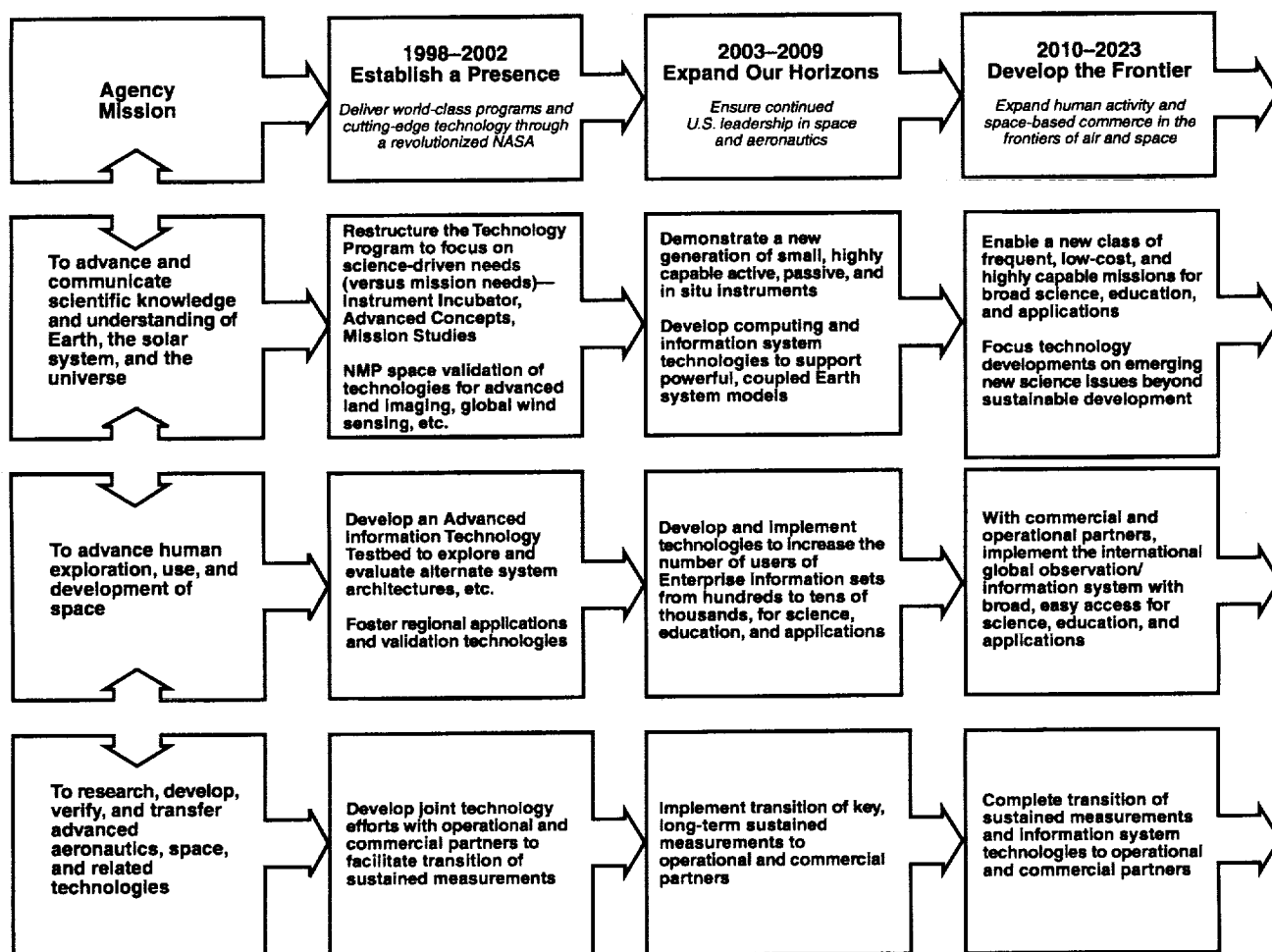
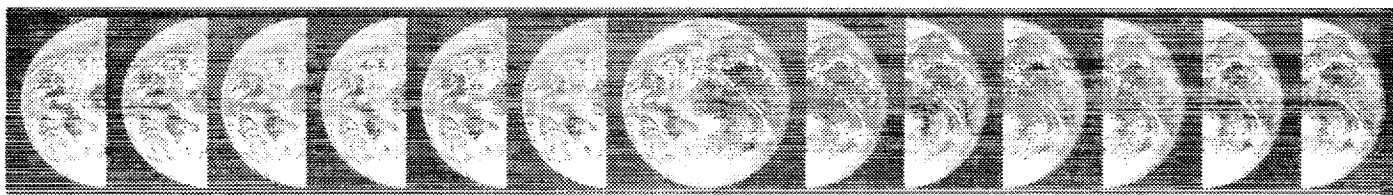


Figure 2. Earth Science Enterprise Strategic Technology Roadmap

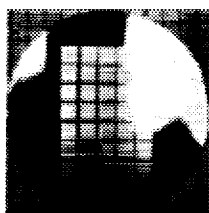
- Mechanical and electronic innovations that simplify design, fabrication, and operation and provide significant reductions in spacecraft system and subsystem resource requirements
- Increased levels of spacecraft and/or ground system autonomy that streamline operations and that simplify and reduce the cost of the command, control, and monitoring of the flight segment
- Onboard data fusion and interinstrument data comparison for autonomous, multi-instrument campaigns and onboard, adaptive data acquisition strategies combining multiple resources, including multiple spacecraft, airborne, and ground capabilities
- Advanced communications concepts that permit extremely high-bandwidth data communications, including cross-linked space-to-space and space-to-ground capabilities



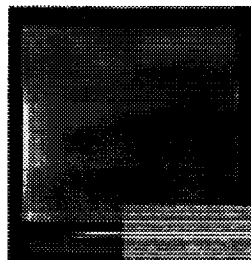
**Advances in sensor technologies will enable smaller, more capable remote-sensing instruments.**



Quantum Well  
Infrared  
Photodetectors



Smart Focal Planes



Lithographic Optics



Miniature Optical Systems

Integrated Terahertz Receiver Technology

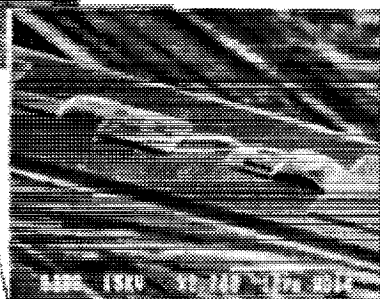


Figure 3. Examples of Enabling Technologies

- Systems platform concepts and innovations for cost-effective deployment and operations of air-, surface-, and subsurface-based sensors

## Information Systems

Advanced end-to-end mission information system technologies will collect and disseminate information about the Earth system and enable the productive use of Enterprise science and technology in the public and private sectors. These include:

- Improvements in collecting, compressing, transmitting, processing, distributing, and archiving data from multiple Earth remote- and in-situ-sensing platforms

- Effective approaches for linking multiple data sets and for extracting and visualizing information to develop predictive environmental models of the global Earth system

ESE also recognizes the potential of emerging technology breakthroughs to enable heretofore unenvisioned approaches for addressing Enterprise science priorities. We will seek and exploit these “technology push” opportunities through ESE and cross-Enterprise advanced concepts programs.

1. The first part of the document discusses the importance of maintaining accurate records of all transactions and activities. It emphasizes the need for transparency and accountability in financial reporting.

2. The second part of the document outlines the various methods and techniques used to collect and analyze data. It includes a detailed description of the experimental procedures and the statistical analysis performed.

3. The third part of the document presents the results of the study. It includes a series of tables and graphs that illustrate the findings of the research. The data shows a clear trend of increasing activity over time.

4. The fourth part of the document discusses the implications of the findings. It suggests that the results have significant implications for the field of study and may lead to further research in this area.

5. The fifth part of the document concludes the study. It summarizes the key findings and provides a final statement on the importance of the research.

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## Section IV

# Investment Strategy

**T**he investment strategy of the ESE technology development program provides a framework for setting priorities among competing capability needs and among diverse technology solution options. The overall approach derives from the roadmap illustrated in Figure 2 and from the philosophy conveyed by Figure 4. The approach emphasizes the more direct link between science or applications research and the Enterprise's technology initiatives.

In the near term (1998–2002), the science and applications needs “pull” the technology investments—that is, the measurement needs are very well defined, so the short-term technology investments typically are focused on reducing aspects of total mission costs. In the midterm (2003–2009), a mixture of science “pull” and technology “push” is planned. Here, the science and applications needs are again relatively well defined, but there is opportunity and time for creative, new technology-driven ideas to emerge. A mix of cost savings, increased measurement system performance, and new measurement capabilities is sought. The New Millennium Program is an example. In all cases, the near- and midterm investments strive to ensure that key technologies will be available to support a 3- to 4-year acquisition cycle for upcoming missions currently in formulation.

In the far term (2010–2023), the focus is on attacking the very challenging science and applications questions. Here, technology can create entirely new measurement concepts and operational scenarios that can enable or “push” previously unforeseen science investigations and applications. This requires continued investment in very advanced instrument and spacecraft component technologies and information systems architectures and capabilities. These are incorporated into the planning, implementation and

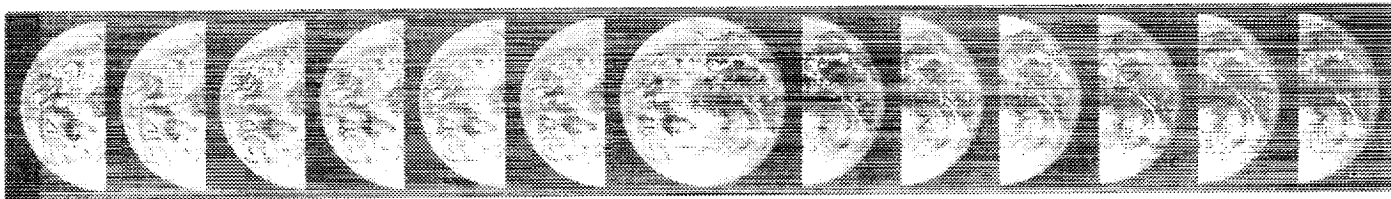
assessment of the ESE Technology Development Program to optimize the benefits to the Enterprise.

### *a. Ensure that Enterprise technology programs consider near-, mid-, and far-term horizons*

ESE is committed to implementing a program of scientific investigation that is sustainable over the long run. This requires a continuing flow of new, affordable capabilities emerging from the technology pipeline and a concomitant balance of near-, mid-, and far-term objectives, as defined in Appendix 4. Under the assumption that the NASA Cross-Enterprise Technology Development Program will focus primarily on the early stages of technology development, and with the understanding that technology development becomes more costly in later stages, the desired proportion of the ESE-focused investment in near-, mid-, and far-term objectives is 60 percent, 25 percent, and 15 percent, respectively. To guard against the potential for longer term technology investment budgets to be diverted to meet near-term programmatic needs, decisions that must weigh the relative benefit of the two areas are examined at the highest levels of Enterprise management.

### *b. Maintain a traceable link between science and applications objectives and technology investment*

Following Agency guidance, ESE is establishing a more direct and strengthened linkage between science and technology that then defines or benefits specific mission implementations. This model of “Science Objectives, Technology Options, Mission Definition,” depicted graphically in Figure 4, offers a number of advantages over the traditional “Science, Mission, Technology” paradigm in which technology was developed within the projects, and project-specific needs dictated the priorities. The new approach calls for technology prioritization



### Shift From Technology Derived From Missions to Missions Enabled by Technology

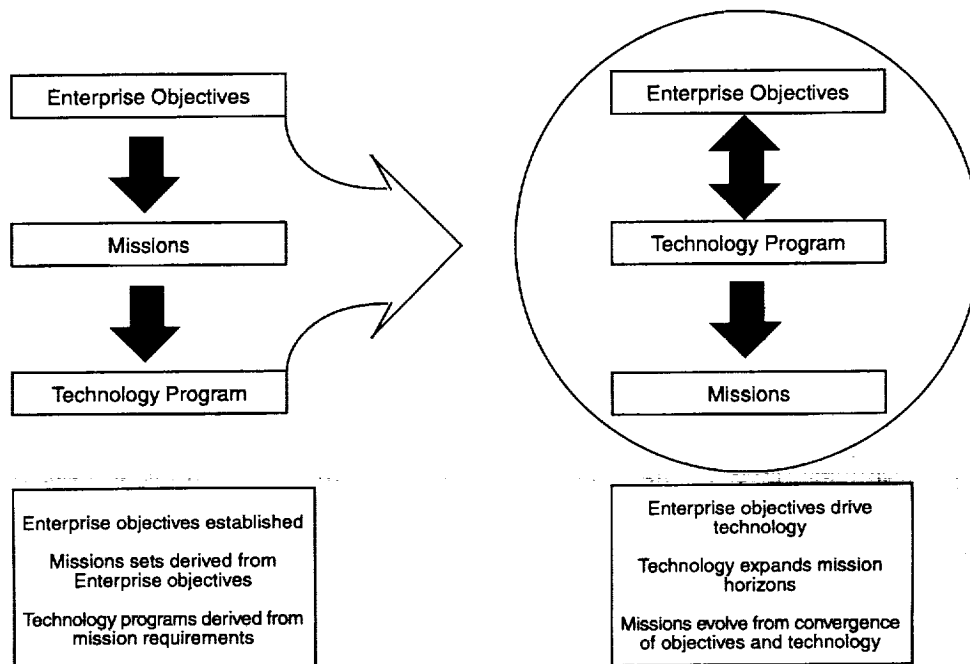


Figure 4. New Paradigm for NASA Technology Investments

based on overall benefit to the Enterprise, and it ensures that technology advances achieved will be available for the benefit of all future missions, including both ESE systematic and process measurements, as well as operational systems implemented through the IPO. Benefits to be accrued include cost reduction as well as performance enhancement. Figure 5 depicts some examples of Earth science and applications opportunities enabled through the infusion of emerging technologies.

**c. Ensure overall program cost-effectiveness through technology advances and application**

As NASA ventures into an era of increasingly constrained resources, technology development for the sake of cost reduction must stand on at least equal footing with development for the sake of performance enhancement. Consolidating the technology program outside of

the projects and linking it directly to ESE research objectives allow program priorities to be compatible with industrial standards and architectures.

**d. Ensure that the Enterprise technology programs support a maximum 3-year acquisition timeline for flight and ground systems**

Three-year acquisition timelines for flight missions and major ground systems leave little opportunity for incorporating new technology unless it is already sufficiently mature by the initiation of the acquisition process. It is therefore a strategy of the Earth science technology program to bring needed technologies to the necessary level of maturity for direct incorporation into flight and ground systems. Likewise, the acquisition of new systems should wait, where feasible, until the needed technology has achieved the required maturity. A close coordination

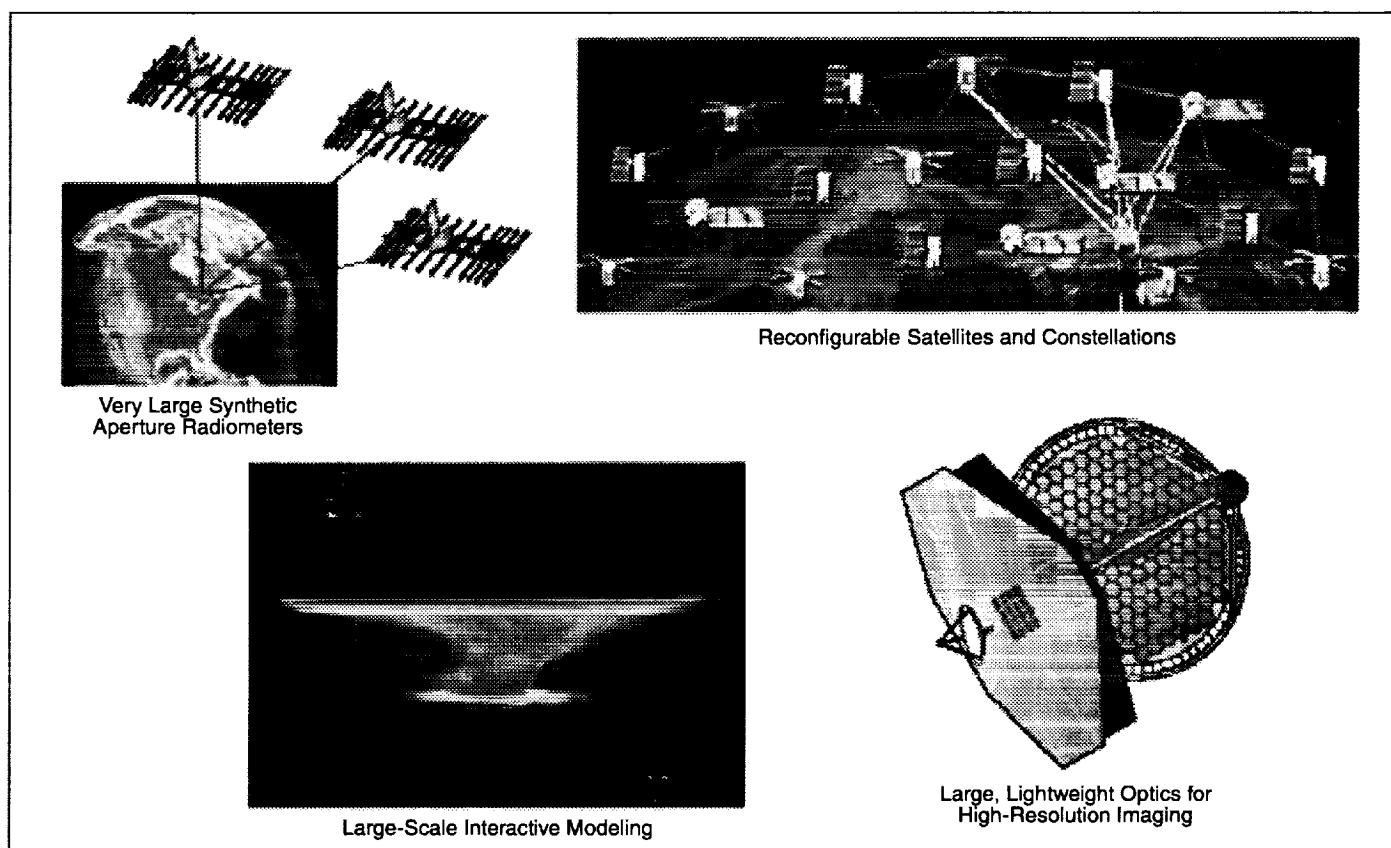
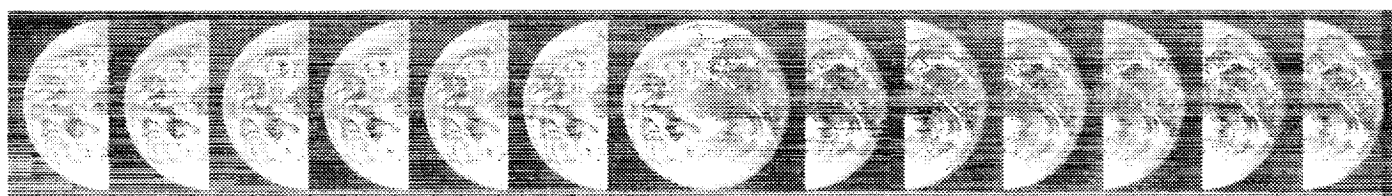


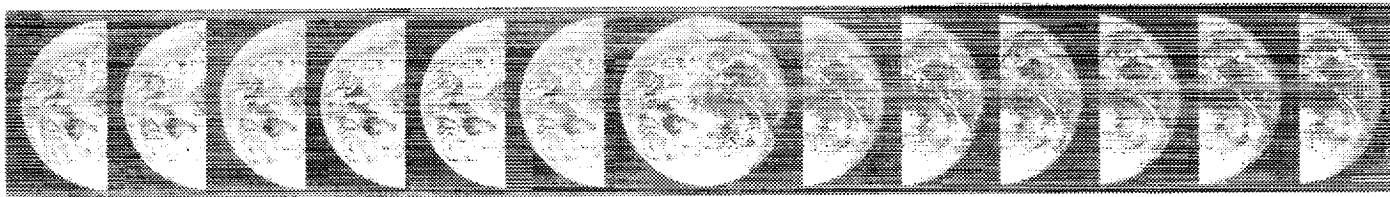
Figure 5. Examples of Earth Science Opportunities Enabled Through the Infusion of Emerging Technologies

must be maintained between technology and mission planning. This ensures a common schedule for technology development to be consistent with the mission implementation, such that the technology will be ready for infusion into the missions and, conversely, that missions are planned to occur when the enabling or cost-saving technology becomes available.

***e. Leverage Enterprise technology investments through creative competition, cross-Enterprise program synergy, and external partnerships***

Open competitions for ESE-supported technology programs will be used as much as possible to attract the best ideas and capabilities from the broad technology community, including industry and academia.

There are many ongoing technology development programs in the public and private sectors that can benefit the Enterprise. An open, competitive environment should draw these out. ESE's strategy is to establish strong links to relevant NASA and other Government agency and private-sector programs during planning and implementation phases, to maximize mutual leverage and benefit. Systematic leverage of synergistic technology programs allows ESE resources to be focused on critical needs not available from other sources. Internally funded activities within the private sector are more difficult to penetrate because of proprietary considerations; however, we strive to find innovative partnerships with the private sector. Equity and balance will be sought in the partnerships to ensure that each participant is gaining its anticipated return on investment.



Thus, partnerships will be sought with the other Government agencies and with industry. Those with industry will be to develop capabilities in the commercial sector that meet future requirements for Earth science data acquisition. For those key cutting-edge technologies in which ESE has a continuing strategic interest to meet long-term scientific goals, and there is no existing commercial driver to stimulate development within the private sector, the Enterprise shall establish sustained investments at selected NASA Centers and strive to transfer this technology to industry at an appropriate level of maturity. In these cases, NASA Centers will bring their ideas and core capabilities into play through Headquarters-managed competition for technology development activities.

**f. Focus Enterprise resources on critical, high-payoff ESE technology needs through an integrated technology planning process**

ESE has developed an integrated technology planning process that starts with the Enterprise research goals and measurement continuity requirements and systematically carries the requirements through to specific technology performance objectives. This planning process consolidates the requirements of many potential missions and investigative scenarios and allows a synoptic perspective of ESE's technology needs. Technology solutions are then sought that meet critical needs and offer the greatest value across the Enterprise. More enabling technologies are shown in Figure 6.

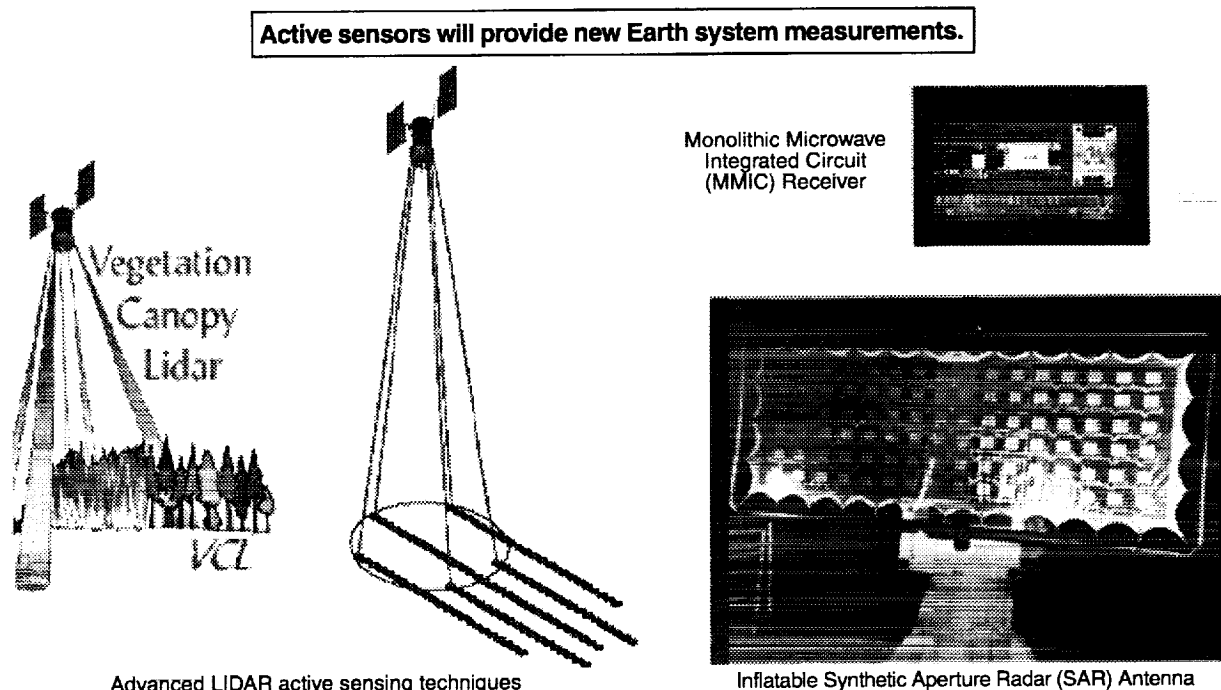


Figure 6. Examples of Enabling Technologies



## Section V

### Planning Process

**A**s an outcome of the 1997 Biennial Review, ESE has adopted an integrated planning process that starts with the science and applications research priorities and measurement continuity requirements and systematically carries the requirements through to specific technology performance, thereby retaining a direct traceability back to the science drivers. The technology planning process is also coordinated with Enterprise acquisition and implementation plans. This ensures a common schedule for technology development and mission implementation; such missions are planned to occur when the enabling or cost-saving technology becomes available. Conversely, technology development schedules are coordinated to achieve the maximum benefit for mission timelines predicated on measurement continuity requirements and science roadmap priorities.

ESE has assigned responsibility for implementation of the ESE Technology Development Program to the Earth Science Technology Office (ESTO) at the Goddard Space Flight Center and to the Jet Propulsion Laboratory (JPL) for the New Millennium Program. Both the ESTO and New Millennium Program offices will also support the strategic technology planning and formulation activities at Headquarters. ESTO will carry out its functions utilizing expertise from across the NASA Centers.

The adoption of an integrated planning process is the key to ensuring the effective use of ESE resources for technology development. The system capability drivers derive directly from the ESE fundamental and applied research priorities, and the technology priorities are generated through trade studies that compare the relative merits of different implementation options in terms of life-cycle cost reduction and improved or enabled capability to perform priority science investigations.

The technology planning process begins with the ESE planning process that provides science and applications research-driven ESE measurements, goals, priorities, and timelines. Using this as a starting point, the planning process proceeds through four steps resulting in a set of periodically updated documents:

- The ESE Capability Needs Assessment defines the systems-level capability requirements derived from the fundamental and applied research measurement priorities.
- Technology Options and Trade Studies translate the systems capabilities into technology performance requirements and compare the relative merits of competing approaches.
- The Integrated Technology Development/Investment Plan provides prioritized technology goals and the plan for achieving them through NASA and external technology development programs.
- The Technology Infusion Plan identifies which of the planned missions are expected to incorporate the technology advances as they are achieved.

ESE will update these documents periodically and make them available through appropriately accessible web sites (see Appendix 2). Figure 7 summarizes the inputs from and returns to the science and technology communities. Appendix 3 provides a detailed description of the planning process steps and documents. The success of the ESE Technology Development Program depends heavily on the ability to leverage activities in other technology development programs, both within NASA and other Government agencies as well as in the private sector.

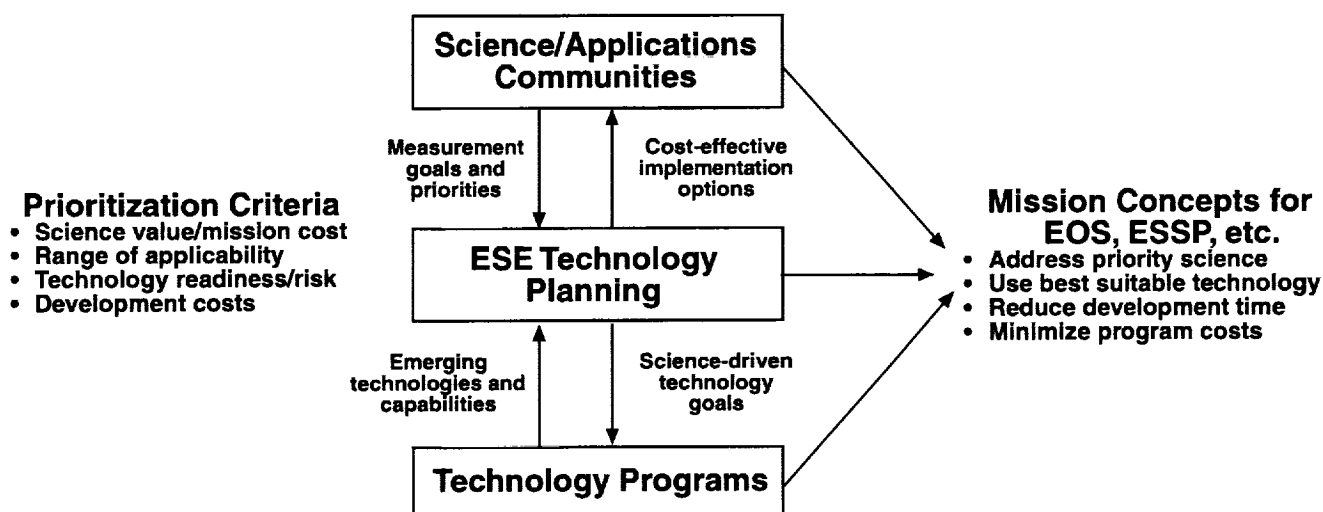
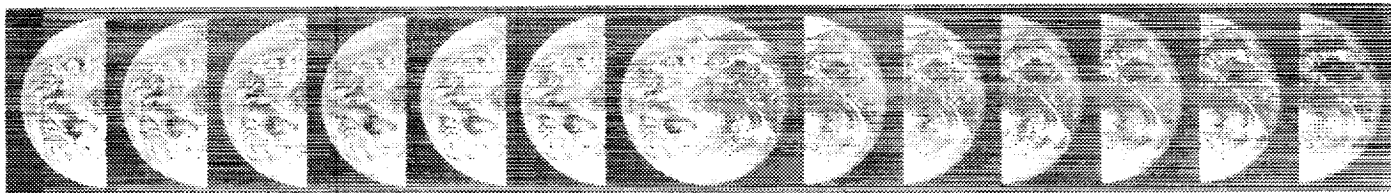


Figure 7. Earth Science Enterprise Technology Planning Strategy

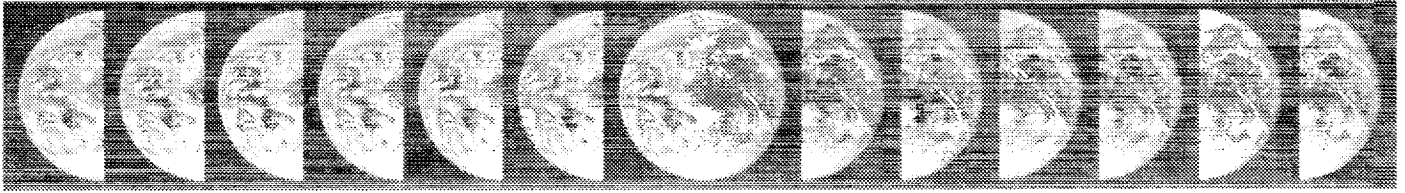
Links to other technology users and providers are maintained through the formation of a technology coordination group or team. Membership represents the full range of ESE science, technology, and implementation programs, as well as other NASA and external technology development programs relevant to ESE needs.

To augment the annual internal assessment, ESE has established an external review board by convening a Technology Subcommittee (TSC) of the Earth System Science and Applications Advisory Committee (ESSAAC). TSC membership is selected from the academic community, industry, and other Government agencies, based on their expertise in Earth system science and technology fields. The TSC chair is also a member of ESSAAC. The TSC will be asked to review the planning, content and outcomes of the Technology Development Program periodically.

Finally, to ensure that the benefits of the investment in technology are realized, ESE must identify and implement appropriate new strategies for infusing the advances into future science and applications research missions. Many of

the future ESE missions will be managed in the Principal Investigator (PI) mode, in which the PI has the responsibility for decisions regarding the incorporation of new technologies into the mission. Under these conditions, ESE must strive to create the situation in which it is in the PI's best interest to adopt the technology advances achieved and fly the best possible systems. Ultimately, if the new technologies offer significant cost savings and/or performance enhancement in high-priority fundamental and applied research areas, incorporating these advantages into mission designs should increase a PI's chance of generating a winning proposal. This should, in turn, serve as a strong motivator for proposers to take advantage of the new capabilities in designing their missions, as long as the new technologies do not introduce unwarranted levels of risk into their mission design.

The coming era will also see increased reliance on commercial space assets for acquiring science data. To ensure that space missions built and maintained within the private sector do, indeed, offer cost-effective alternatives, the new technologies must be effectively transitioned into private industry.



Thus, ESE must ensure that information on the capabilities and maturity of new technologies is broadly disseminated to reach the appropriate communities, that the technologies are valuable and truly available for user incorporation, and that the associated risk to the first user

is appropriately mitigated. The Technology Program will have its ultimate success judged on the degree to which the developed technologies are infused in future programs both within ESE and in cooperating programs.







## Program Elements

**T**he integrated technology planning process consolidates the requirements of all Enterprise fundamental and applied research objectives, creating a synoptic perspective of ESE's technology needs. This has stimulated a new look at the way in which ESE utilizes and benefits from its own technology development programs, as well as those supported by other NASA Enterprises, other Government agencies, and the private sector.

ESE's technology strategy seeks to leverage the entire range of technology development programs offering benefits in cost, performance, and timeliness of future Earth science process and monitoring campaigns. Some of these programs are under the management of ESE, and others are chartered to support the needs of multiple organizations, including ESE. Still others may be leveraged by ESE only through the inherent or negotiated synergy of requirements and goals based on joint support and mutual leverage.

ESE is committed to an allocation of 10 percent of its overall annual budget to technology development, as a means of achieving its challenging vision for fundamental and applied research at an affordable cost. The ESE-supported technology program is composed of three elements.

### *a. Advanced Concepts*

For the generation of new component and system concepts, ESE provides its own Advanced Concepts studies and initiatives. Driven by high-level science and applications research goals and system-level requirements, this set of activities explores new component, system, and architectural concepts with a time horizon of typically 10 to 20 years.

The products of this effort are concepts developed as paper studies or proof-of-concept based on modeling. Promising ideas are incorporated into the Capability Needs Assessment and trade studies that determine the ESE Level 1 and 2 requirements, which are used as inputs to other technology development programs. The ESE Advanced Concepts effort complements more general activities within the NASA Institute for Advanced Concepts (NIAC) with ESE-specific analyses.

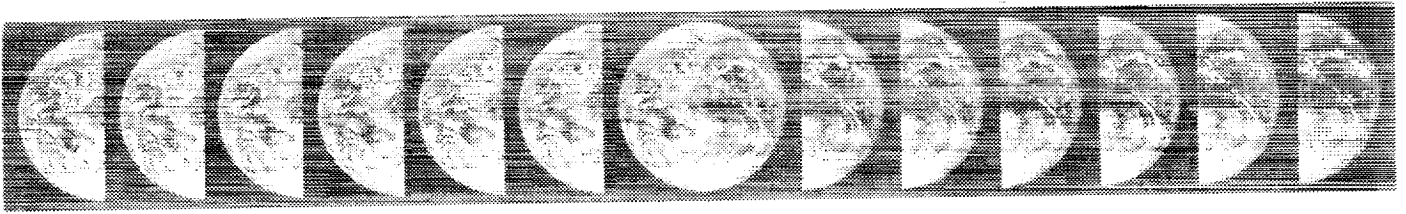
### *b. Advanced Technology Initiatives*

#### *b1. Mission and Trade Studies*

Under this element, activities are supported to focus and refine ESE technology requirements, including system trade studies and the development of technology roadmaps. Architectural concepts developed under the Advanced Concepts element are carried forward to determine the specific system, subsystem, and component performance metrics required for their implementation.

#### *b2. Technology Development*

The Advanced Technology Initiatives element also advances key component and subsystem technologies required for the next generation of process and monitoring missions. An example is the current Sensors and Detectors Program, which includes the development of lidar technologies for profiling winds and chemical constituents within Earth's atmosphere, spectrometers that can return high-quality EOS Level 2 science products at lower total mission cost, and radiometers for passive microwave and millimeter-wave remote sensing. These activities are complementary to the Cross-Enterprise Technology Development Program (CETDP), managed through the Space Science Enterprise, NASA's



primary advanced technology program for developing component and subsystem technologies at early stages of maturity. While CETDP has the charter for generic technologies with value to multiple NASA Enterprises, ESE's Advanced Technology Initiatives element is focused on technologies specific to ESE needs. Finally, funding under Advanced Technology Initiatives is used to accommodate joint venturing with other Enterprises, Government organizations, and the private sector. Relevant NASA programs include the Space Operations Management Office (SOMO) Technology Program, the Environmental Research Aircraft and Sensor Technology (ERAST) Program, and the Small Business Innovation Research (SBIR) and the Small Business Technology Transfer (STTR) Programs. External to NASA, the U.S. Air Force technology programs in space vehicles, sensors, and information have considerable overlap with ESE capability needs, as do various programs within the Army, Navy, National Reconnaissance Office, and Department of Energy.

Designated representatives of these programs are invited to participate in the ESE technology coordination efforts. Mutually beneficial partnerships are also sought with the private sector and funded under the Advanced Technologies Initiatives element. More enabling technologies are in Figure 8.

### *c. Focused Technology Programs*

In some cases, component and subsystem technologies developed under or in partnership with the Advanced Technology Initiatives element may be appropriate for direct incorporation into fundamental and applied research campaigns. However, in many cases, the end product of these programs typically require further system integration and/or validation prior to first use.

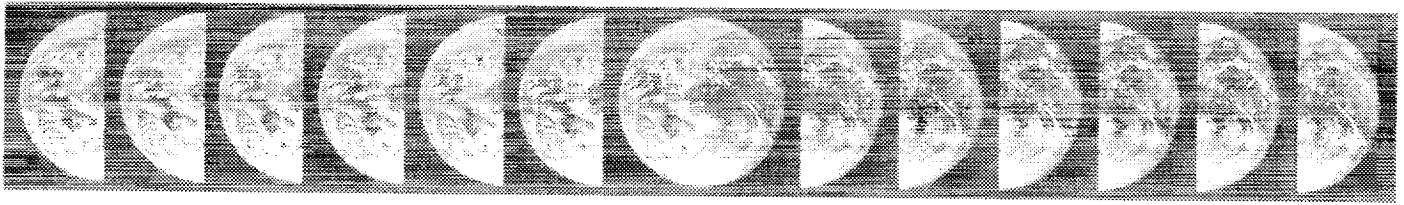
ESE supports several project areas focused on specific high-priority technology areas and their integration into

system capabilities. These include the development of new instruments and measurement techniques under the Instrument Incubator Program (IIP); the development of advanced information systems technologies as ESE-unique information systems development initiatives or through the High Performance Computing and Communications (HPCC) Program; and flight validation of critical instrument and spacecraft capabilities within the New Millennium Program.

IIP supports the development of new instruments and measurement techniques from paper studies through laboratory development and ground or air validation. NASA Research Announcements (NRA) are used as the vehicle to search the combined public and private science/technology community for the best new ideas and development capability. See Figure 9 for some other examples of enabling technologies.

Other programs develop capabilities relevant to ESE's needs, including the Environmental Research and Sensor Technology (ERAST) Program by the Aero-Space Technology Enterprise of NASA and various defense and intelligence agency programs. ERAST is developing low-mass, low-power, long-duration unmanned aerospace vehicles that may meet some of ESE's needs, especially for multisensor remotely piloted aircraft campaigns. Examples of overlapping instrument needs external to NASA include Synthetic Aperture Radar, lidar, and hyperspectral imaging capabilities important to the Air Force, Navy, and intelligence agencies for the surveillance and reconnaissance of hostile activity, as well as to the Department of Energy for the detection of signatures indicating production of weapons of mass destruction.

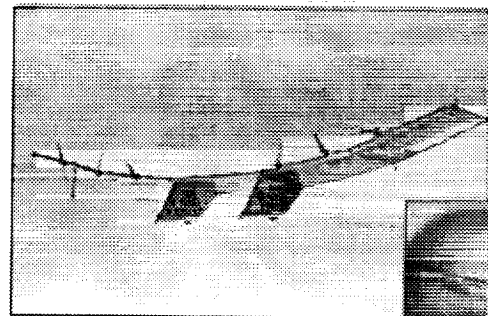
For next-generation technologies and systems, ESE supports the development of relevant capabilities in industry through programs such as the Commercial Remote Sensing Program. The significant growth of the communications satellite industry already under way and



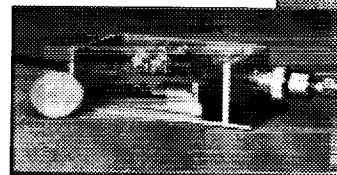
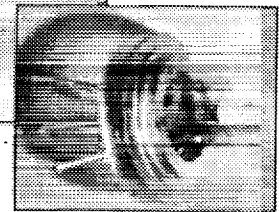
**Miniature, self-contained deployable sensor packages will enable low-cost networks of in situ instruments.**



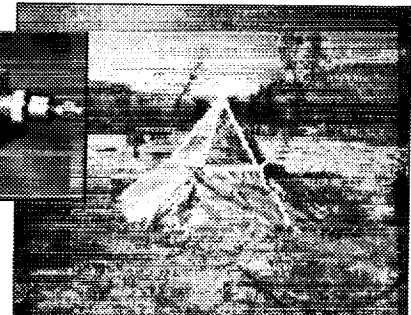
Surface  
Acoustic Wave  
Hygrometer



Tunable Diode Laser  
Spectroscopy



Unattended Micro  
Seismometers

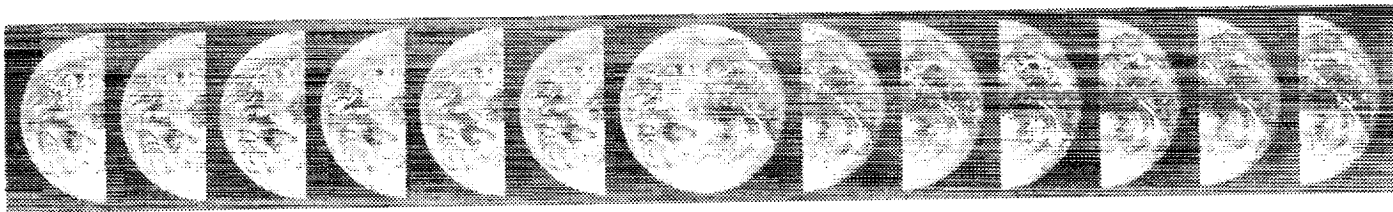


*Figure 8. Examples of Enabling Technologies*

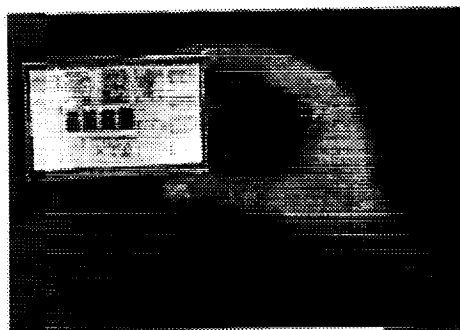
the anticipated proliferation into other commercially lucrative remote-sensing areas lead to a future with a large number of commercial satellites in a variety of orbits. Figure 10 shows another enabling technology.

Depending on the nature of the technology under development, it may be necessary to go beyond laboratory demonstrations to mitigate the risk prior to its first use in a space mission. Space platform and instrument technologies that require operational space flight validation are candidates for the New Millennium Program (NMP),

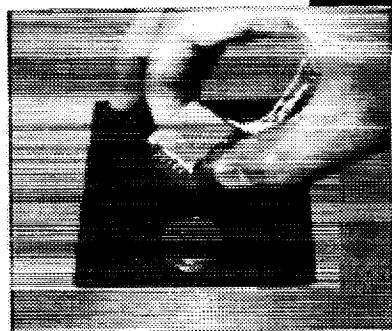
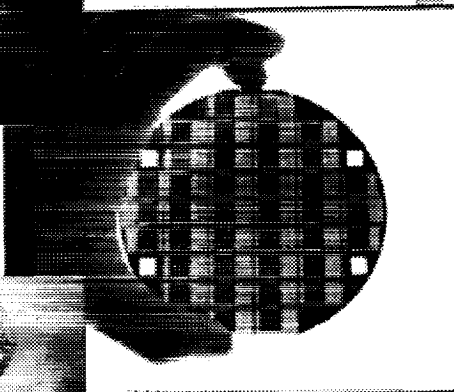
which is jointly funded and managed by ESE and the Space Science Enterprise and merges the high-priority needs of multiple NASA offices to identify the most critical capabilities for validation. ESE's needs are brought to NMP through the NMP Science Working Group, which includes representation of the ESE science and applications research themes. Candidate capabilities for NMP flight validation are selected on the basis of their impact on future science and applications research missions, the degree of breakthrough represented by the underlying technologies, and the need and value of operational vali-



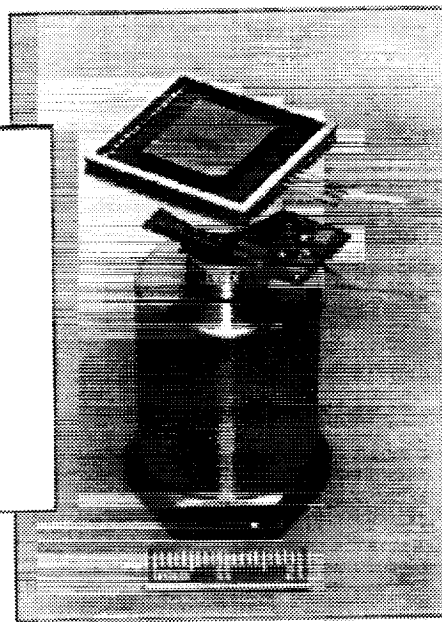
**Chip-level miniaturization of spacecraft functions will enable constellations of microsatellites applicable to a range of Earth science measurements.**



GPS-on-a-Chip



Microgyro



Subliming-Solid Thruster

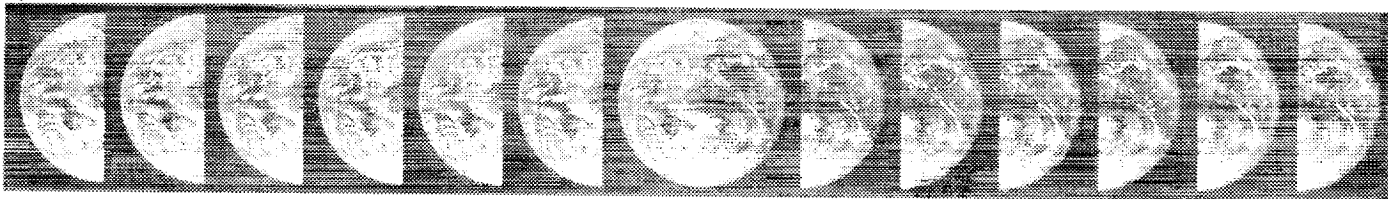
*Figure 9. Examples of Enabling Technologies*

dation. NMP makes the validation results public so that system providers as well as mission proposers and managers can access the information for use in future space missions.

ESE will also seek opportunities to leverage ground and flight validation programs of other Government agencies, particularly those of the Armed Forces and the intelligence agencies, where there is expected to be considerable synergy in capability needs. Relevant flight test programs include the Integrated Space Technology Development Program sponsored by the Air Force and

the space technology research vehicle flights of the Ballistic Missile Defense Organization.

The interrelationships between ESE and other relevant NASA technology programs are depicted in Figure 11, and a more detailed description of the individual programs is provided in Appendix 4.



**The direct delivery of information products to users will extend the benefits of ESE science and applications research to a broader community.**

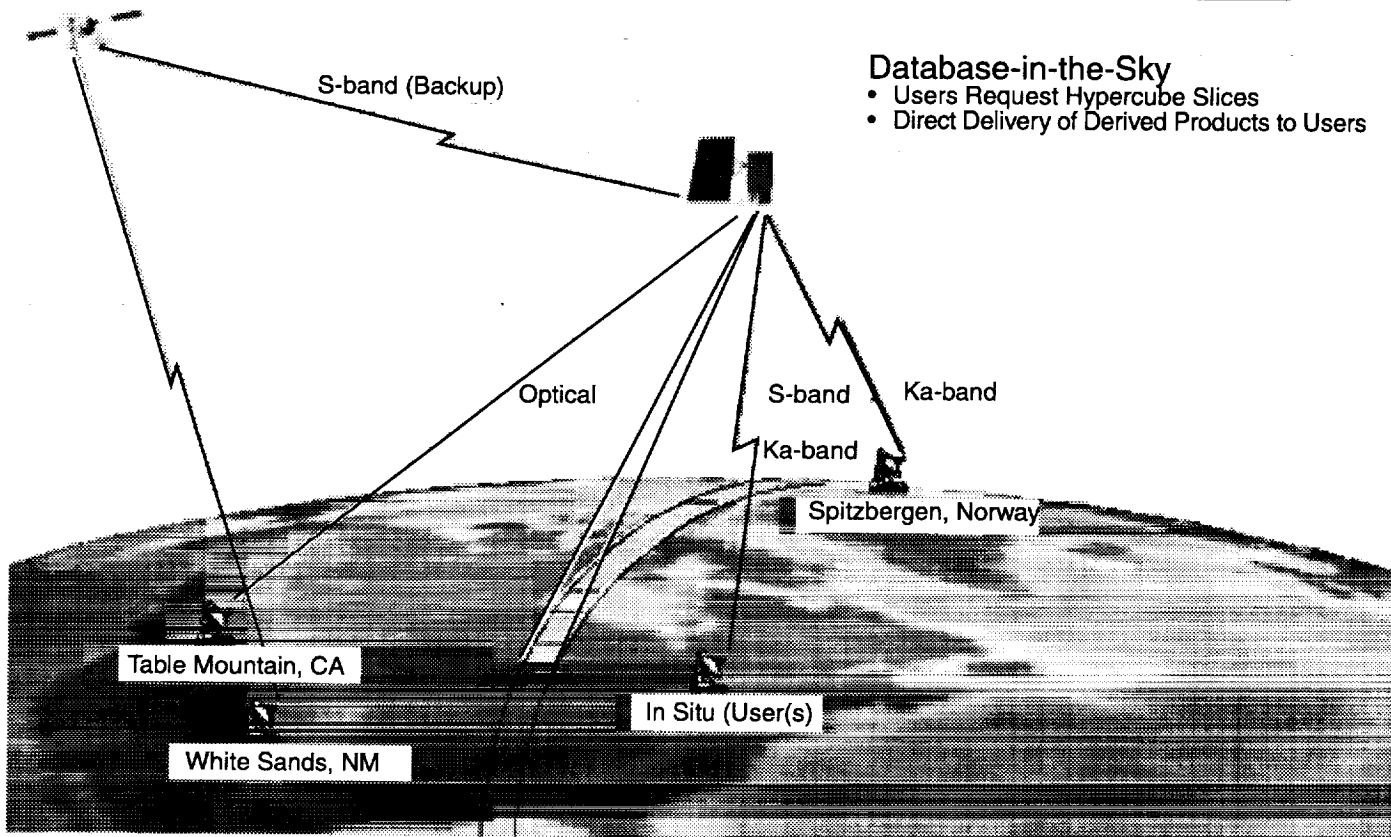


Figure 10. Examples of Enabling Technologies

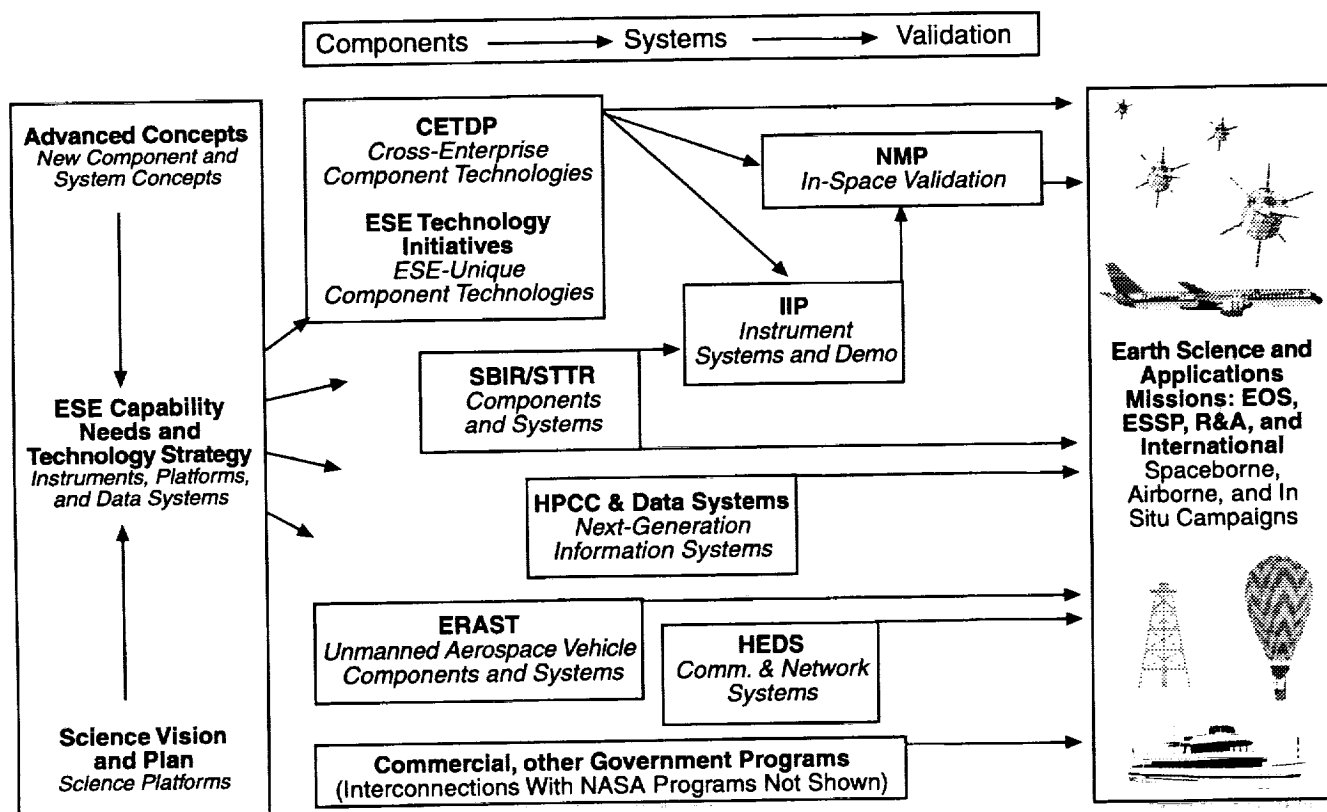
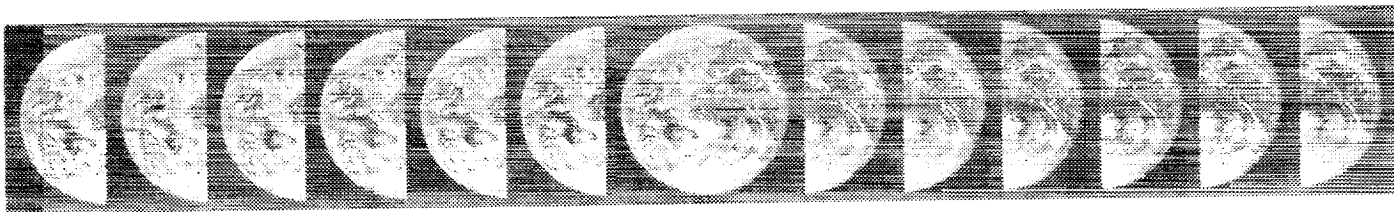


Figure 11. Technology Development Programs Benefiting ESE



## Metrics

**E**SE will assess programs annually against its technology performance criteria. This will include an examination of the program content against the six specific strategies defined in Section IV. Specific metrics for each of these objectives are as follows.

***a. Ensure that Enterprise technology programs consider near-, mid-, and far-term horizons***

**Supporting Metrics:**

- ESE Technology funding allocated at 50 percent for near-, 25 percent for mid-, and 25 percent for far-term development
  - Cross-enterprise technology funding at 50 percent for mid- and 50 percent for far-term development
- b. Maintain a traceable link between science and applications objectives and technology investment***

**Supporting Metrics:**

- Periodic (as often as annually) ratification of the Capability Needs Assessment database by ESE and the TSC of ESSAAC
- Formal configuration management and reporting process for technology investment plans

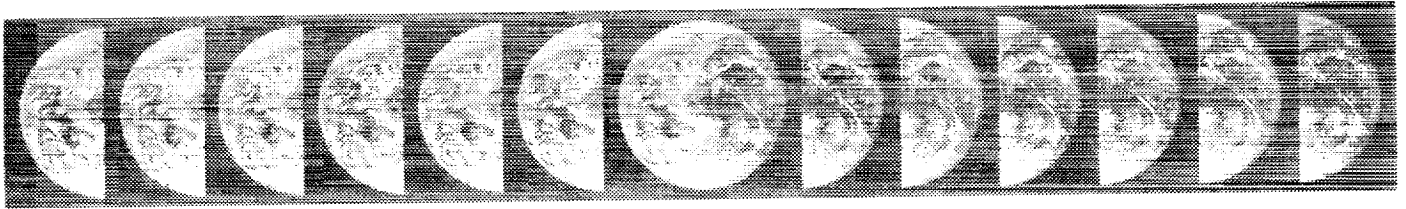
***c. Ensure overall program cost-effectiveness through technology advances and application***

**Supporting Metrics:**

- At least 25 percent of ESE-funded development tasks advance annually by at least one Technology Readiness Level (TRL), as defined in Appendix 4
  - Annual adoption of at least one ESE-supported technology development by a commercial entity for potential industry application or demonstration through the NASA Commercial Remote Sensing Program at Stennis Space Center
  - Biennially enabling at least one new science measurement capability via a technology-push acquisition or development
- d. Ensure that the Enterprise technology programs support a 3-year acquisition timeline for flight and ground systems***

**Supporting Metric:**

- At least 15 percent of near-term technologies annually attain a maturity level appropriate for mission implementation in 3 years or less



- e. Leverage Enterprise technology investments through cross-Enterprise program synergy and external partnerships*

**Supporting Metrics:**

- Annually ensure that ESE technology requirements are included in solicitations by all supporting NASA technology programs—specifically, CETDP, SBIR, HPCC, NIAC, and the SOMO technology initiatives
- Annually establish at least one joint agreement with a technology program external to NASA that results in the inclusion of at least one ESE requirement

- f. Focus Enterprise resources on critical, high-payoff ESE technology needs through an integrated technology planning process*

**Supporting Metric:**

- Annual update and ratification of the Integrated Technology Development/Investment Plan by ESE

**Overall Assessment Metrics: Achieve success in timely development and infusion of technologies**

**Supporting Metrics (as a periodic assessment):**

- Lower the total life-cycle costs (including technology development) for existing and soon-to-be-launched missions
- Maximize the total life-cycle cost-effectiveness of planned missions, both for long-term systematic measurement and for exploratory missions
- Stimulate new science and applications initiatives as a result of technology developments

Metrics will be established at key planning and implementing levels of the program and evaluated in terms of their success in guiding and controlling the program. These metrics will be reassessed periodically for their effectiveness in promoting and reflecting the desired results.





# Appendix 1

## Acronyms

CETDP	Cross-Enterprise Technology Development Program
CRSP	Commercial Remote Sensing Program
DoD	Department of Defense
EOCAP	Earth Observing Commercial Applications Program
EOS	Earth Observing System
ERAST	Environmental Research Aircraft and Sensor Technology (Program)
ESE	Earth Science Enterprise (also Office of Earth Science and NASA Code Y)
ESSAAC	Earth System Science and Applications Advisory Committee
ESSP	Earth System Science Pathfinder
ESTO	Earth Science Technology Office (at Goddard Space Flight Center)
FY	Fiscal Year
GPS	Global Positioning System
HPCC	High Performance Computing and Communications (Program)
IIP	Instrument Incubator Program
IPO	Integrated Program Office (the tri-agency office formed to manage the converged NOAA and DoD NPOESS program)
ISE	Intelligent Synthesis Environment
JPL	Jet Propulsion Laboratory
MMIC	Monolithic Microwave Integrated Circuit
NASA	National Aeronautics and Aerospace Administration
NIAC	NASA Institute for Advanced Concepts
NMP	New Millennium Program
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NRA	NASA Research Announcement
PI	Principal Investigator
SAR	Synthetic Aperture Radar
SBIR	Small Business Innovation Research Program
SOMO	Space Operations Management Office
STTR	Small Business Technology Transfer Program
TDP	Technology Development Program
TRL	Technology Readiness Level
TSC	Technology Subcommittee (of ESSAAC)





# Appendix 2

## Reference Web Site URL's

ESE Strategic Visions	<a href="http://www.hq.nasa.gov/office/ease/visions.html">http://www.hq.nasa.gov/office/ease/visions.html</a>
ESE Capability Needs Assessment	<a href="http://ntrpio.nasa.gov/esto/doctree.html">http://ntrpio.nasa.gov/esto/doctree.html</a>
ESE Level 1 Technology Requirements	<a href="http://ntrpio.nasa.gov/esto/doctree.html">http://ntrpio.nasa.gov/esto/doctree.html</a>
ESE Science Research Plan	<a href="http://www.hq.nasa.gov/office/ease/draftsciplan/toc.htm">http://www.hq.nasa.gov/office/ease/draftsciplan/toc.htm</a>
ESE Trade Studies Results	<a href="http://ntrpio.nasa.gov/esto.html">http://ntrpio.nasa.gov/esto.html</a>
Instrument Incubator Home Page	<a href="http://ntrpio.nasa.gov/iip/index.html">http://ntrpio.nasa.gov/iip/index.html</a>
New Millennium Program Home Page	<a href="http://nmp.jpl.nasa.gov">http://nmp.jpl.nasa.gov</a>
NASA SBIR and STTR Home Page	<a href="http://sbir.gsfc.nasa.gov/SBIR.html">http://sbir.gsfc.nasa.gov/SBIR.html</a>
NIAC	<a href="http://niac.usra.edu">http://niac.usra.edu</a>
Commercial Remote Sensing Program	<a href="http://www.crsp.ssc.nasa.gov/nindex.html">http://www.crsp.ssc.nasa.gov/nindex.html</a>





# Appendix 3

## ESE Technology Planning Process

To ensure the timely availability of needed technology, ESE will implement a systematic process to identify and prioritize its technology needs. The process will be driven by the ESE fundamental and applied research priorities and requirements for measurement continuity, and it will establish a clear connection between these measurement goals and the derived technology performance requirements (see Figure 12).

As detailed below, the ESE technology planning process proceeds through four steps resulting in a set of regularly updated documents:

- The ESE Capability Needs Assessment defines the systems-level capability requirements derived from the science and applications research measurement priorities.
- Technology Options and Trade Studies translate the systems capabilities into technology performance requirements and compare the relative merits of competing approaches.
- The Integrated Technology Development/Investment Plan provides prioritized technology goals and the plan for achieving them through NASA and external technology development programs.
- The Technology Infusion Plan identifies the planned missions that will incorporate the technology advances as they are achieved.

### Capabilities Needs Assessment

This document incorporates as a starting point the science and applications research measurement priorities (including the operational Integrated Program Office

needs) as documented in the Science and Applications Implementation Plans from the Enterprise science and applications divisions at NASA Headquarters. Timelines for these elements will be derived from the implementation planning carried out as part of the candidate Flight Mission Profile development by ESE Headquarters. The ESE Capabilities Needs Assessment shall trace Earth Science Enterprise capability needs and opportunities from the fundamental science and applications research themes:

- To the Earth system quantities that need to be established to support the research theme
- To the physical measurements that could be used to provide the Earth system quantity
- To the implementation options that could be used to achieve the measurement
- To the system requirements and challenges for the implementation option

The quantitatively defined system requirements represent the unprioritized, comprehensive summary of ESE technology development drivers.

### Technology Options and Trade Studies

Studies, workshops, and other activities will be implemented to translate the systems needs into technology performance requirements and to assess the relative merit of implementation options to achieve priority Earth science measurements. These activities, supported under the ESE Advanced Technology Initiatives, shall assess:

- Technology performance metrics needed to meet the system requirements and challenges

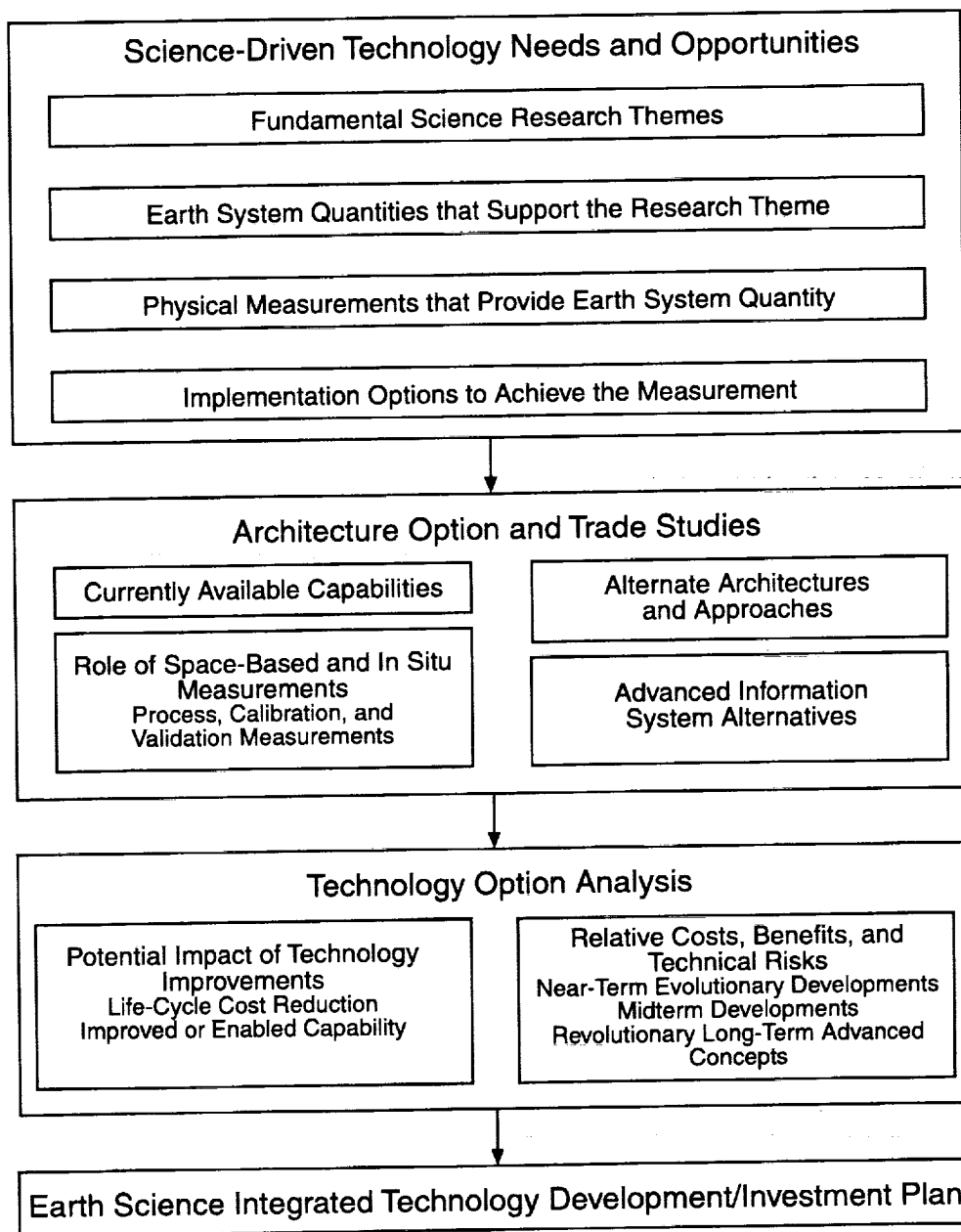
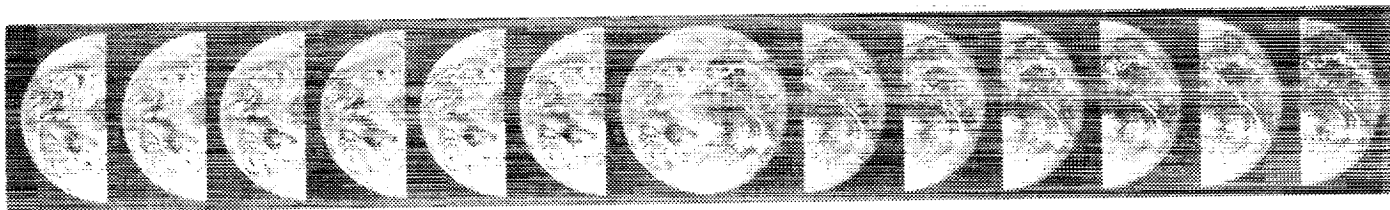
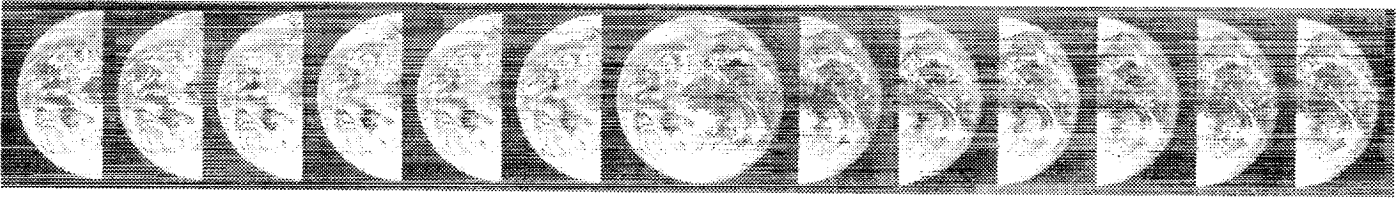


Figure 12. Earth Science Enterprise Technology Planning Process



- Currently available capabilities and those requiring technology development
- The potential impact of technology improvements in terms of both life-cycle cost reduction and improved or enabled capability
- The relative merit of alternate measurement, implementation, and technology options to address the fundamental and applied research priorities
- The relative costs, benefits, and technical risks of near-term evolutionary developments, midterm developments, and revolutionary, long-term advanced concepts
- Identified opportunities for leveraging synergistic investments by outside organizations
- Agreements with NASA and non-NASA technology programs for the desired development
- Plans for ESE investment to address remaining technology goals

#### **Technology Infusion Plan**

Coming full circle, the plans for incorporating the technology advances to the benefit of future missions and critical decision points are documented in the Technology Infusion Plan. Established during the candidate Flight Mission Profile development, these need dates are incorporated as the driving schedules in the next round of technology planning. The coordination of the ESE plans for mission implementation with the technology development plans is necessary to ensure the timely infusion of the achieved advances.

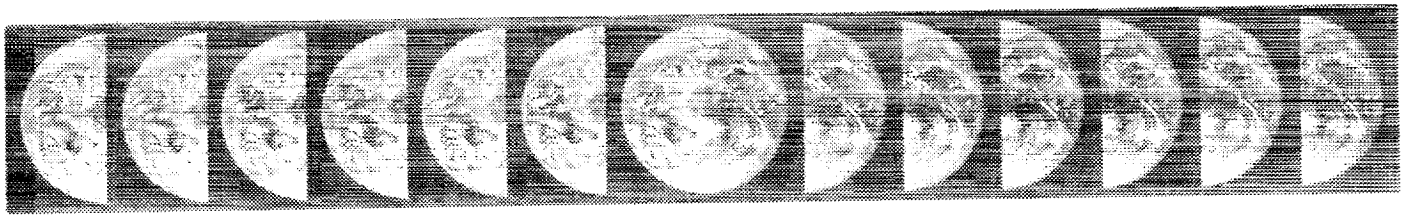
The results of these activities will be documented as reports and used as inputs for program prioritization incorporated in the Integrated Technology Development/Investment Plan.

#### **Integrated Technology Development/Investment Plan**

Based on the results of Technology Options and Trade Studies above, priorities will be defined for near-, mid-, and far-term technology development goals. These goals will serve as the guide for ESE and NASA cross-Enterprise investments. They will also be used to identify leverage opportunities within external technology development programs.

The optimized plan for achieving the priority technology development goals within the range of available technology development programs constitutes the Integrated Technology Development/Investment Plan and includes:

- Prioritized technology development goals, including performance metrics and readiness dates
- Broadly disseminate information on the capabilities and maturity of new technologies to potential mission proposers (and reviewers), mission implementers, and flight and ground system providers



- Bring the technologies to an appropriate level of maturity for incorporation within 3-year acquisition timelines
- Validate the new capabilities to the extent required to bring down the risk to first users to an acceptable level
- Work with industry to ensure that the resulting products and capabilities are truly available for user incorporation by transferring new capabilities to industry providers and by adopting commercial standards and architectures where feasible



# Appendix 4

## Technology Development Programs Benefiting ESE

### A. Program Characteristics

The technology programs of value to ESE differ in many factors, including the time horizon of their development objectives, the generic versus application-specific nature of the product, the degree of technology maturity sought as the goal of the development, and the focus on component, subsystem, system, or architecture development or validation. To assist in the characterization of the individual programs and the elucidation of their interdependencies, the following characteristics are defined:

- Technology readiness. The technology maturity steps approaching readiness for incorporation in a science mission are reflected in the NASA Technology Readiness Level (TRL) scale displayed in Figure 13.

One of the important characteristics of a technology program is the range of TRLs it spans.

- Time horizon. The designations near-term, midterm, and far-term are used to represent technology development objectives to mature the technologies to a level appropriate for acceptance in a science mission (typically TRL 7) within 3 years, between 3 and 6 years, and beyond 6 years, respectively.

### B. Description of Relevant NASA Technology Programs

A brief description is provided of each of the relevant technology development programs whose benefits to ESE are discussed above. The characteristics of these programs are captured in Table 1.

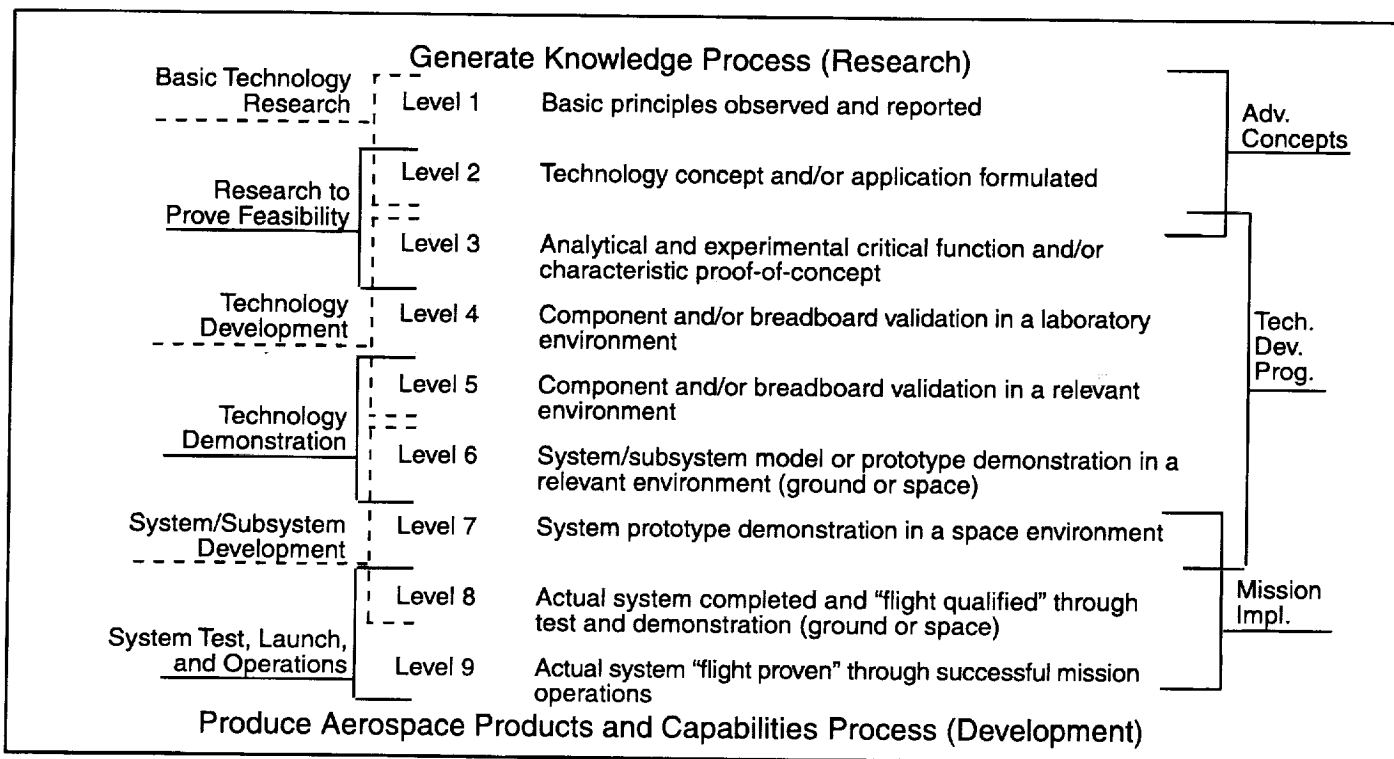
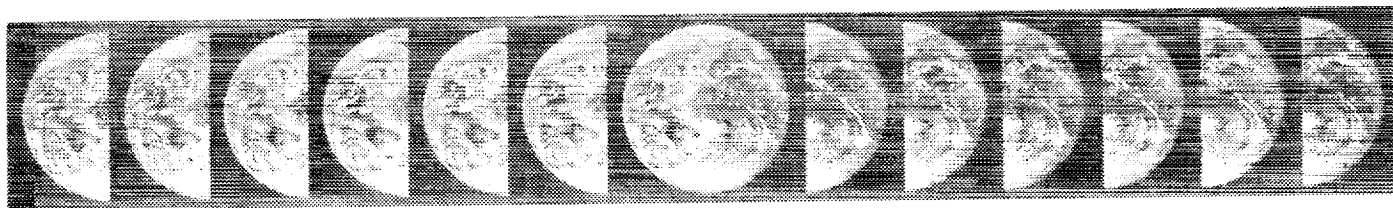
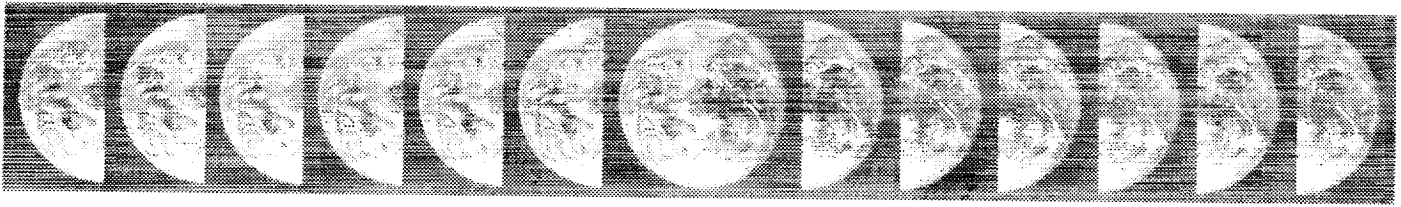


Figure 13. NASA Technology Readiness Level Definitions



Program	Time Horizon	TRL Range	Product Type	Focus Areas	Sponsor(s)
Commercial Remote Sensing Program (CRSP)	Near & mid	4 to 9	Verification and validation technologies	Commercial remote sensing	ESE
	Near & mid	3 to 6	Decision system technologies		
	Near & mid	6 to 8	Technology infusion		
ESE Advanced Concepts	Far	2 to 4	Components, systems, & architectural concepts	ESE-specific concepts complementing NIAC	ESE
ESE Advanced Technology Initiatives	Near, mid, & far	2 to 6	Studies, roadmaps, components, & subsystems	ESE-specific needs and joint activities with other programs	ESE
ESE Focused Technology Programs	Near, mid, & far	2 to 6	Subsystems & systems	Includes IIP, NMP, and HPCC	ESE
Environmental Research Aircraft & Sensor Technology (ERAST)	Near & mid	6 to 8	Components, instruments, & flight systems	Remotely piloted aircraft and associated instrumentation	Aero-Space Technology Enterprise
High Performance Computing & Communications (HPCC)	Mid & far	2 to 6	Components & systems	Computing & communications systems for ground & space	Aero-Space Technology Enterprise
Instrument Incubator Program (IIP)	Mid & far	2 to 6	Instruments & sensing techniques	ESE instrument needs	ESE
NASA Cross-Enterprise Technology Development Program (CETDP)	Near, mid, & far	Predominantly 2 to 4, some 5 & 6	Primarily component	NASA crosscutting technology areas	Space Science Enterprise
NASA Institute for Advanced Concepts (NIAC)	Far	1 to 3	Components, systems, & architecture concepts	All NASA areas of interest	NASA
New Millennium Program (NMP)	Near & mid	Predominantly 7 & 8, some 5 & 6	Space flight validated components & systems	Breakthrough areas of interest to science Enterprises	Joint ESE and Space Science Enterprise
Space Science Enterprise Focused Technology Programs	Near, mid, & far	2 to 6	Components and systems	Development in support of future Office of Space Science science missions	Space Science Enterprise
Small Business Innovation Research (SBIR)	Mid to far	3 on	Studies and concept development through market infusion	NASA-wide	NASA
Small Business Technology Transfer (STTR)	Mid to far	2 on	Studies and concept development through market infusion	NASA-wide	NASA
Space Operations Management Office (SOMO)	Near & mid	6 to 8	Operations technology & systems	Flight operations	Office of Space Flight

Table 1. NASA Technology Programs Benefiting ESE



### Commercial Remote Sensing Program (CRSP)

The mission of CRSP (<http://www.crsp.ssc.nasa.gov/index.htm>) is to maximize U.S. industry's use of remote sensing and related space-based technologies and to develop advanced technical responses to spatial information requirements. CRSP responds to the challenge of assisting U.S. firms in developing state-of-the-practice technologies that cost-effectively support this market through facilities and expertise.

CRSP represents a major ESE initiative to move away from developing and maintaining unique and expensive space infrastructure. The commercial remote-sensing industry is a rapidly growing global industry with both aeronautical and space-based components. Industry (private sector) and ESE (public sector) are complementary, and technologies, products, and services flow bidirectionally:

- Commercial remote-sensing industry data products and technologies support NASA's discovery and scientific initiatives.
- NASA science mission data and technology feed the commercial industry.

CRSP is chartered to foster U.S. commercial leadership in the global commercial remote-sensing market and to foster commercial sources of data and technology to meet the needs of NASA's discovery and scientific initiatives. Currently, CRSP is engaged in four major programmatic initiatives: the Earth Observing Commercial Applications Program (EOCAP), Cooperative Research and Development, the Affiliated Research Centers, and the Scientific Data Buy Program.

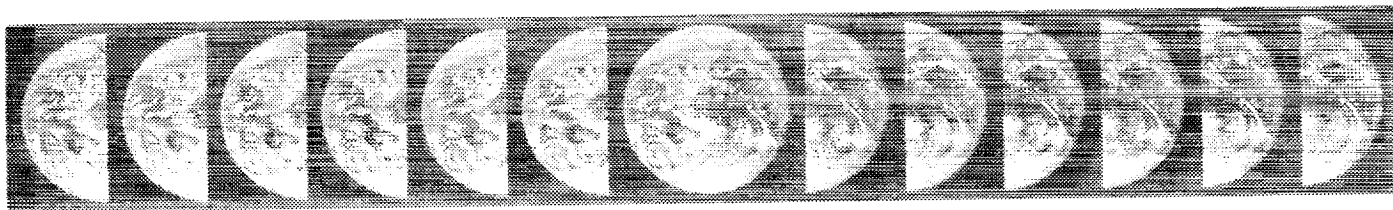
Removing technological barriers is essential to promoting and maintaining U.S. leadership in the commercial remote-sensing industry and to achieving the ESE goals of reducing its science data costs while expanding access. As such, a core function of CRSP is guiding NASA's technology programs to meet the commercial remote-sensing industry's technology needs. Strategic guidance for the relationship between ESE technology and industry technology is provided through the "CRSP Technology Plan." The technology infusion roadmaps provided in this plan are developed by jointly considering the needs of the science and commercial communities. These roadmaps guide the formulation of ESE programs implemented by NASA Technology Centers in partnership with industry, academia, and Government laboratories.

### ESE Advanced Concepts Program

ESE sponsors the Advanced Concepts program to support the development of far-term, Enterprise-specific technologies, complementing the far-term architectural studies carried out within NIAC.

### ESE Advanced Technology Initiatives

This element of the ESE Technology Development Program supports the development of Enterprise-specific component and subsystem technologies. It supports activities to focus ESE requirements, define technology roadmaps, and refine reference mission scenarios. It also includes the development of needed components and subsystems that are not covered under the Space Science Enterprise's Cross-Enterprise Technology Development Program. It provides for ESE-unique advanced information systems technology development. Also, it provides funding for joint venturing and partnerships with other Government programs as well as commercial leveraging.



## Environmental Research Aircraft and Sensor Technology (ERAST)

The ERAST Program (<http://erast.arc.nasa.gov/erast/erast1.html>) is a NASA initiative to develop and flight-demonstrate remotely piloted aircraft for cost-effective fundamental and applied research missions. Two science mission flight profiles have been identified by the science community as being critical to the collection, identification, and monitoring of environmental data for the assessment of global change. The first is flight to extreme altitudes, defined as the region between 80,000 to 100,000 feet. The desired payload capacity is 500 pounds, with a minimum time on station of 2 hours. The second mission is defined as exceeding 96 hours in continuous operation at altitudes from 50,000 to 75,000 feet carrying a minimum payload of 1,000 pounds.

In addition to air vehicle development, ERAST is actively pursuing a course toward a new class of lightweight, low-power consumption scientific sensors. The ambitious goals of this effort are to reduce weight by a factor of 5 and constrain total power consumption to less than 50 percent of the current suite of instruments.

## High Performance Computing and Communications (HPCC)

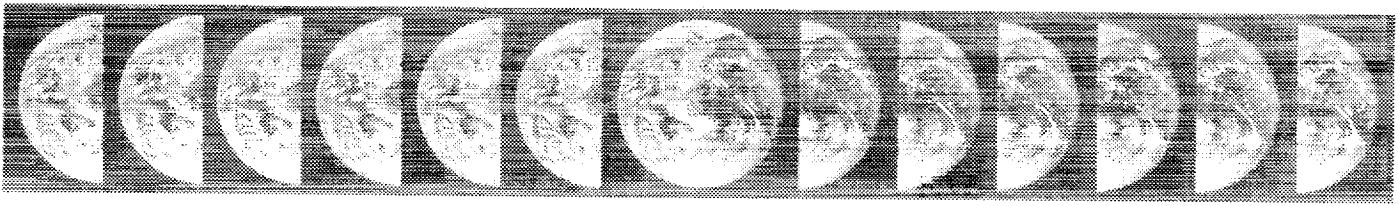
NASA's HPCC (<http://www.aero.hq.nasa.gov/hpcc>) Program is aimed at boosting supercomputer speeds by a factor of 1,000 to at least 1 trillion operations per second—1 teraflop—and communications capabilities by 100-fold. HPCC is a crosscutting multi-Enterprise program receiving funds from the Aero-Space Technology, Space Science, and Earth Science Enterprises and NASA's Education Program. Through HPCC, NASA is also a major participant in the Next Generation Internet initiative, a multi-agency effort that also includes DoD, the Department of Commerce, the National Science

Foundation, and the National Institutes of Health. Each agency has its own specific role in the Next Generation Internet program to ensure there is no duplication of research. NASA's role is to perform applied research and systems development for the NASA missions in emerging applications, such as advanced aerospace design and test, telemedicine, Earth sciences, astrobiology, astrophysics, and space exploration.

HPCC pursues technologies that are between 5 and 20 years from maturity. Applications in the areas of Earth science, space science, and aeronautics are used as drivers of HPCC's computational technology research, providing the requirements context for the work that is done. HPCC conducts TRL 2–6 research activities intended to prove feasibility and develops and demonstrates computing technologies for eventual introduction into NASA operations. In addition, HPCC conducts education technology outreach demonstrations that are essentially at TRL 7–8.

## Instrument Incubator Program (IIP)

The IIP (<http://mtpe.gsfc.nasa.gov/IIP/iip.htm>) is a technical and managerial approach for enabling the rapid development of new, less costly, and less resource-intensive scientific instruments through the aggressive pursuit and infusion of emerging and revolutionary technologies. This initiative is intended to bring instrument system concepts to the appropriate state of technology readiness so that flight instruments can be developed and delivered within short windows of opportunity. It will utilize component development programs and flight validation opportunities to complete the instrument development chain. This process will expedite technologically advanced instrument systems that collect EOS core data sets used to monitor global change, augment the larger body of planned ESE measurements, and/or enable totally new Earth system science.



### **NASA Cross-Enterprise Technology Development Program (CETDP)**

The objectives of CETDP are to:

1. Develop new critical crosscutting technologies to enable innovative and less costly missions and research concepts for the Earth Science, Space Science, and Human Exploration and Development of Space Enterprise communities
2. Improve performance by orders of magnitude through revolutionary long-term, high-risk, high-payoff technology advances

Crosscutting technologies are defined as those that clearly benefit programs and projects across more than one Enterprise, as well as embryonic technologies that have broad potential to span the needs of more than one Enterprise. The primary focus of the program is to fill the front end of the "technology pipeline" (low TRLs) with technologies capable of supporting revolutionary advances and maturing technologies (higher TRLs) only after partnering with the Enterprises.

### **NASA Institute for Advanced Concepts (NIAC)**

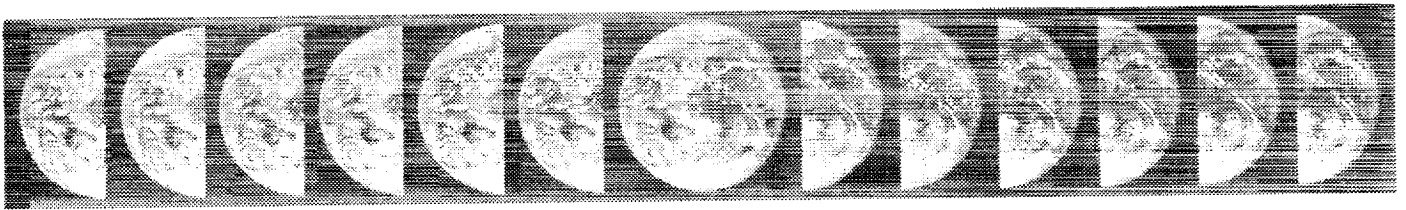
The purpose of NIAC is to provide an independent, open forum for the external analysis and definition of space and aeronautics advanced concepts to complement the advanced concepts activities conducted within the NASA Enterprises. Its focus is on revolutionary concepts, specifically systems and architectures, that can have a major impact on future missions of the NASA Enterprises. The initial period of award for NIAC is 3 years, with an option for 2 additional years.

NIAC is functionally independent of NASA, and the concepts it selects for Government support will be the result of an external review by respected technical experts. NASA intends that the best products of NIAC will be infused into NASA's, and the Nation's, future programs, within the constraint of fiscal realities.

### **New Millennium Program (NMP)**

NASA has recently inaugurated NMP (<http://nmp.jpl.nasa.gov>) to enable exciting 21st century science missions through the identification, development, and flight validation of key emerging technologies and capabilities. Candidate capabilities for NMP flight validation are selected on the basis of their impact on future science missions, the degree of breakthrough represented by the underlying technologies, and the need and value of operational validation as a precursor to first use by a science mission. NMP emphasizes breakthrough technologies that significantly contribute to reducing costs, increasing the frequency, and enhancing the scientific capability of future science missions and that are difficult to incorporate into science missions because of the inherently high risk associated with their first use. NMP seeks advances from the broad technology and science community spanning industry, educational institutions, nonprofit organizations, and NASA Centers and other Government laboratories and agencies.

Validation flights are designed to provide appropriate testbeds for the operational validation of the selected capabilities and to return new science using these capabilities. NMP expects to launch one deep space and one Earth-observing (EO) flight approximately every 18 months. The first NMP EO mission is scheduled for launch in 1999. EO-1 features an advanced land imager and will fly in formation with Landsat 7 to compare the



performance of new multispectral technologies to that of the current Landsat instrumentation. The new technologies have the potential to reduce mass, power, and volume by a factor of 7 for follow-on Landsat-type measurements.

### **Space Science Enterprise Focused Technology Programs**

The Space Science Enterprise sponsors a number of focused technology programs to develop technologies that are enterprise-specific—and therefore not addressed by CETDP. The five current Space Science Enterprise focused technology programs are Mars Technology, Deep Space Systems, Astronomical Search for Origins Technology, Structures and Evolution of the Universe Technology, and Sun-Earth Connection Technology.

### **Small Business Innovation Research (SBIR) Program**

The SBIR program (<http://sbir.gsfc.nasa.gov/SBIR.html>) is a broad, Governmentwide initiative managed by the Small Business Administration. It seeks to foster cooperative research and development through a uniform process having three phases. Phase 1 is intended for a study or conceptual design effort, Phase 2 for prototyping or proof-of-concept, and Phase 3 for infusion into commercial markets and back into NASA with non-SBIR funding. The duration and funding limits for Phase 1 are 6 months and \$70,000, respectively, whereas those for Phase 2 are 24 months and \$600,000. After Phase 1, a NASA TRL of 3 is achieved. After Phase 2, a TRL of 5 or 6, or sometimes higher, is achieved. SBIR funding is established as 2.5 percent of NASA's external R&D budget as mandated by Congress and will be about \$90–\$100 million for FY 2000. The goal of the SBIR program is to support each of the NASA Enterprises equally. This allocates 25 percent of the funding for Earth sciences and 25 percent for space sciences.

### **Small Business Technology Transfer (STTR) Program**

The STTR program (<http://sbir.gsfc.nasa.gov/SBIR.html>) is designed to convert the Nation's investment in research from universities, federally funded research laboratories, and other nonprofit research organizations into new commercial technologies to advance the economic competitiveness of the United States and to meet the technology needs of the Government. STTR draws on the talents of small, innovative businesses to initiate a partnership between them and a research institute of their choice. Proposals submitted in response to this solicitation must include an intellectual property rights agreement. Like the SBIR program, the STTR program has three phases. Research topics for STTR are aligned to the NASA Centers of Excellence as defined in the 1998 NASA Strategic Plan. This results in one topic per NASA Field Center (JPL is not a participant). Within these topics, one or two core technologies for the Centers of Excellence are chosen for emphasis during each solicitation period.

### **Space Operations Management Office (SOMO) Technology Program**

The overall goals of SOMO's (<http://www.jsc.nasa.gov/somo>) mission is to implement Agency space operations goals while successfully providing services that enable Enterprise mission execution. SOMO's technology program supports the following three major themes: to reduce the cost of NASA space operations, to provide enabling data and mission services to the NASA Enterprises, and to advance U.S. leadership in commercial satellite communications.

The Technology Strategy is one of a family of strategic documents being published by NASA's Earth Science Enterprise. Others in the family are the Strategic Enterprise Plan, the Science Implementation Plan, and the Applications, Commercialization, and Education Strategy.

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